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ABSTRACT

The Nordic Conference of 1985 was convened for the purpose of fostering cooperation between science and technology educators within different fields and at different levels, with approximately 40 science and technology educators from Finland, Norway, Sweden, Denmark, India, the United States, and Yugoslavia participating. This report contains 27 contributed papers from the conference. Some of the topics addressed include: (1) teaching with computers; (2) physics instruction; (3) theory of mathematics education; (4) UNESCO's activities in science and technology education; (5) biotechnology teaching; (6) interdisciplinary environmental education; (7) every day chemical phenomena; (8) science and society; (9) student attitudes toward science; and (10) energy education. Also included are small groups and panel discussion reports, the conference schedule, and a list of the participants. (ML)

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NORDIC CONFERENCE ON SCIENCE AND TECHNOLOGY EDUCATION: THE CHALLENGE OF THE FUTURE

8 - 12 May, 1985

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PREFACE

International cooperation in the area of education is of prime importance, especially within science and technology which are changing our lives every day. Regional cooperation among countries with similar problems and potentials such as the Nordic countries is not only of value in itself, but can also provide a starting point for aa true "internationalization" of educational research and development.

In order to promote such cooperation, Unesco recently established an international network for information in science and technology education. Each of Unesco's Member States was invited to nominate a participiping institution. The purpose of the network is to encourage cooperation and exchange of information both on a world-wide scale and also among regional or sub-regional groups of countries with similar conditions and concerns, such as the Nordic countries. The Nordic Conference was organized in the framework of this network, with financial and technical support from Unesco. The Royal Danish School of Educational Studies, which is the Danish member of the network, undertook the organization of the Conference.

In the past many Nordic science and technology educators have considered their problems from a purely national point of view and have not taken full advantage of the possibilities offered by a more extensive international cooperation. Similarly the cooperation in each Nordic country between science and technology educators within different fields or at different levels has frequently been unsatisfactory. Therefore it was the aim of the Nordic Conference not only to bring science educators from all parts of the Nordic region together, but also to let teachers from different fields and different levels work together on their problems which are often common or strongly related.

The Nordic region is in no way isolated from the rest of the world. It is strongly dependent on what goes on in both developing and industrialized countries. Therefore three eminent science educators from other parts of the world: India, the United States, and Yugoslavia were invited to the meeting. Their participation was supported by the Nordic Cultural Fund, and it was of immense importance for the Conference. So was also the participation of Unesco staff members.

The Nordic participants, around 40 science and technology educators from Finland, Norway, Sweden, and Denmark did a remarkable job. They did not only present a large number of valuable results and ideas, but they did that in a very clear and concise way which was essential for the outcome of the Conference. In the small group discussions they worked hard and obtained excellent results.

Organizing a conference may be hard and unpleasant work. In this case it became a pleasure thanks to the sponsors, especially Unesco, and to the outstanding spirit and brilliant work done by the participants. Therefore, one may hope that the Conference also will work as a starting point for future Nordic cooperation in the field of science and technology education.

Erik W. Thulstrup

CONTRIBUTED

PAPERS

SCIENCE TEACHING WITH COMPUTERS

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1. Educational technology - introduction

During the years much effort has been done to help pupils and students to improve their understanding of science. Currently it is often discussed whether **educational technology** can help the students to improve this understanding. We can define educational technology as[1]: any technological system that is used to create or to improve learning environments.

These educational technologies include a great number of different technologies, such as[2]:

1. Computers
2. Database systems
3. Telecommunications
4. Television
5. The video discs

Computers are both microcomputers, minicomputers and main-frame computers. In consequence of the increases in the capabilities and the decreases in the cost, microcomputers are currently the dominant technology in education in some countries and will reach that status in many more countries within the next decade. The microcomputer is a highly **interactive** medium, in comparison with the other educational technologies.

Database systems are helpful in all sorts of education. They vary from large systems implemented on mainframes to smaller systems on microcomputers.

Telecommunication is a relatively new sort of educational technology, but holds a great deal of promises, especially in distance learning environments like the so-called 'open universities'.

Television does not need many comments. It is the oldest of the educational technologies. And like any educational technology it is better suited for some teaching styles than for others.

Also the **video-disc** is a relative newcomer to educational technology. Potentially it seems to be a very valuable technology in education, but in practise the production cost of the video-disc might prevent . the use in university and school science education.

2. The computer in the classroom

The focal point for the following discussion will be the microcomputer and the practical teaching.

Among the different modes of using the computer in the classroom, I distinguish between[3]:

A. Computer based aids, including:

a. **systems for word processing**, which are very powerful aids for developing writing skills. And although such skills are not directly within the scope of the science education, the word processing systems might be convenient aids for the preparation of reports.

b. **Spreadsheets** which permit the exploration of 'what if?' questions in systems characterized by sets of algebraic equations.

c. **programs for data collection**, which permit students to focus on the interpretation of data rather than on its collection.

d. **software that plots and labels graphs**. This way of use also includes curve fitting.

B. Computerbased learning-environments, in which the major principle is learning **through** computers. This mode of computer use includes:

a. **question-and-answer tutorials,**

b. **drill and practise 'sergeants'.**

Learning through computers is a computer-controlled learning mode as compared with learning **with** the computer. The major focus of research and development in educational computing has been on this mode of use. And most of the programs currently available can be categorised as being based on this principle of use.

Many of the programs within this category do not make the full use of the **interactive** potentials of the computer. Often the computer is not used for nothing but electronic page-turning purposes. However, this does not mean that this electronized page-turning mode cannot at all be useful in fostering learning. This can especially be true, if it is used very carefully as part of a total approach in the educational system. In other words, this can especially be true if the computers are regarded as add-on devices which ought not to replace anything else[4].

C. Computerbased learning-environments in which the major principle in learning is learning with computers. This mode of computer use includes:

a. **The use of the computer as a simulator** of real nature phenomena, which otherwise would have been inaccesible to the pupil and the student because of danger, equipment cost, complexity, time, scale etc. The mode provides the student with a varied and extensive collection of examples within the field of science.

b. **Microworlds** represent a combination between simulations and aids. In this mode the students 'discover' important concepts by experimentation, rather than by traditional didactic methods[5].

The microworld mode of use means using the computer to create an environment in which learning can occur. Of the three mentioned ways this is the most sophisticated way of using computers, and therefore also the most difficult to implement. Currently it is the least developed of the three, but opinions have been expressed that it will be one of the most important mode of use in the future. I agree in that point of view.

3. Learning through and with computers

Exploring the difference between learning **through** and learning **with** computers a little further, the two modes of use can be contrasted. We can do so with help from the following scheme covering the spectrum of modes of use[6]:

	<—— Spectrum of modes of operation ——>	
System characteristics:	Fixed systems Closed systems	Flexible systems Open systems
Focus on:	Problem solving (What is...?)	Problem generating (What if...?)
	Results	Processes
	Training	Discovering
	Competition	Cooperation
Debugging:	Errors = negative	Errors = positive
Behavorial objectives:	Specific knowledge	General conceptions
	Specific skills	General strategies

In the learning mode within the right side of the spectrum the pupils and the students 'discover' important concepts by experimentation rather than by traditional didactic methods, as for example training.

With the use of the microcomputer for training purposes in particular, and with the mode of use called learning **through** computers in general, we are within the left side of the spectrum. However, it seems to be the general opinion among teachers on primary, secondary and tertiary level, that the promises of the computer do not lie in this way of using microcomputers in science education. The promises lie elsewhere in the use of the microcomputer: 1. as an aid, and 2. as a new medium for learning, partly complementing existing teaching methods and partly opening up entirely new possibilities. This last-mentioned way of use, the learning with the computer, is towards the right side of the spectrum.

4. When should the computer be used in education?

In the previous sections I have touched the problem of when and how we can use computers in education. The problem can, as it has been done in a famous way by professor Joseph Weizenbaum, be formulated in the following way: 'Giving that we can do something with a computer, should we?'

The question is rethorical. When putting it that way I think that professor Weizenbaum intends to warn us against modes of use, that are technology led, e.g. modes of use of the type: 'Solutions in search of a problem'.

However, there are two points of view when designing and evaluating educational technology, which might serve as fruitful alternatives to the technology led mode of use. Both will be discussed in the paragraphs which follow.

Within the scope of the first viewpoint we may ask ourselves what can be done with the microcomputer in education, which could not be done before the appearance of this sort of educational technology. In this perspective it is relatively easy to recommend when the computer is going to be used. To put it in very general terms, we can say that the use of the computer in education has much to recommend itself, when implications are[7]:

1. an improvement of existing approaches
2. the introduction of desirable new approaches
3. the deletion of obsolete existing approaches

Implications No.1 and No.2 are self-evident. As a matter of fact they have not emerged with the advent of educational technology. They have existed implicitly in education since its beginning. Implication No. 3 is one of the often overlooked consequences of the advent of educational technology. The point is that the possibility of some new type of activity may cause us to question a traditonal approach.

The first point of this highlighting of implications of computer use is considerations on what students in general can. However, as mentioned above, there is another fruitful way of evaluating the computer use which completes the first mentioned criteria. This may appear when we focus our attention on more specific needs of the students. The starting point would then be considerations on what pupils and students cannot do. Hereby we are touching the problem of learning difficulties and special needs of the students.

In the following scheme I have listed some of the potentials of the computer, when talking about learning difficulties and about what some of the students cannot do immediately[8]:

Student **Special needs:**	*Potentials of the* **Interactive systems:**
1. 'Restricted' ability to deal with abstractions; need for concrete experience	Simulations, microworlds and games can reduce the gap between the concrete and the abstract
2. 'Lack of' intellectual curiosity	The interactive nature of the microcomputer promotes and rewards enquiry
3. 'Lack of' ability to make generalisations and to learn from experiences	Graphics and high-lighting associations can foster personal involvment and active learning; students can acquire and retain concepts on the background of an extensive and a varied collection of examples
4. 'Problems' with transfer of learning to new contexts	Increased confidence and student-control encourage risk-taking; externalising of the students 'system of thought' through modelling fosters transfer; the same goes for the use of microcomputers [illegible] context where students can express and shape complex ideas

5. Conclusion

I think we are now able to conclude that the microcomputer is a rich and complex aid that is increasingly within financial means of schools and universities to acquire. Like any educational aid, it implies inherent advantages and disadvantages. And it is in no way the final answer to all the educational and pedagogical ills.

The computer is more appropriate for some uses than others. Therefore, when contemplating educational computing, the difficult question is not of the type 'how to...', but rather a question of 'whether or not to...'.

The prospects seem to be most promising in those cases where it is used: 1. as a versatile tool for e.g. word processing, collection of laboratory dates, plotting of graphs, or fitting of curves, and 2. in the mode of use which has been called learning with the computer.

And in both cases the computer depends on the human qualities of the designer of the courseware for its use. A.B. Ellis[9] was right in claiming that the prospects seem to be most promising in those cases where thinking of computers' role in education does not mean thinking about computers - but thinking about education.

Notes

1. Cf. L. Braun: "Report on Educational Technology", J. of Educ. Technology systems, vol 12(2), 1983/84. For other definitions of educational technology see F. Percival & H. Ellington: "A Handbook of Educational Technology", Kogan Page Ltd., 1984.

2. Cf. L. Braun: "Report on Educational Technology", J. of Educ. Technology systems, vol 12(2), 1983/84.

3. Cf. L. Braun: "Report on Educational Technology", J. of Educ. Technology systems, vol 12(2), 1983/84.

4. As to the concept of microworld see B. Lawler: "Designing Computer-Based microworlds", in M. Yazdani (ed): "New Horizons in Educational Computing", Ellis Horward Ltd., 1984.

5. Cf. J. Hebenssttreit: "Micro-computers in secondary education", in E.D. Tagg: "Microcomputers in secondary education", North Holland Publ. Company, 1980.

6. Part of the subspecification of the possible roles of the computer in education is similar to the experiences from educational experiments in primary schools in Odense, Denmark.

7. Cf. D. Burnett: "Logo for teacher education", in M. Yazdani (ed): "New Horizons in Educational Computing", Ellis Horward Ltd., 1984.

8. Parts of the subspecification of the potentials of interactive computer systems are similar to the experiences with the use of the computers in special education.

9. Cf. A.B. Ellis: "The Use and Misuse of Computers in Education", McGraw-Hill, 1974.

Changes in Science and Technology Education in Physics in the Danish Gymnasium

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(Gymnasium is Danish for upper secondary school, age 16-19 years.)

After 9 or 10 years in "folkeskolen" (primary and lower secondary school) the danish pupils may continue their theoretical education for 3 more years in the Danish Gymnasium. Since the mid 60-s the Danish Gymnasium has been a great success having a great number of applicants. Today about 30% of an age group attend the gymnasium whereas only 10% did so 20 years ago.

The students choose 1 of 2 sides, the modern side or the science side. The modern side has a science content of about 10% (mathematics, geography, biology), whereas the science side has about 40% on the science (advanced maths and physics), chemical and biological lines (mathematics, physics, chemistry, biology, geography) and about 30% (the same subjects) on the social science and musical lines of the science side.

For the last 20 years especially the science side has been successful. About 2/3 of the students are here. The greatest change is that the girls now attend this side. The increase is from about 1000 girls in the sixties to about 6000 in the eighties. There is now an even distribution between girls and boys on the science side. This is not the case on the modern side, where the girls dominate.

The great increase in the number of students on the science side (from 4000 to 15000 in 20 years) has not changed the number of students taking advanced maths and physics much. The increase is mostly due to the boys. As a matter of fact the percentage of girls taking maths and physics on a high level has constantly decreased from 65% in the mid 60-s to now 25% of all girls on the science side.

Many changes in society and in the educational system have influenced the education in physics. Of special interest for the science education in the gymnasium is

- education in physics/chemistry starts in 7'th year of school, when the pupils are about 14 years old. Sex roles are difficult to change at that age and much research have shown, that this problem is especially related to education in physics

- most "folkeskole" teachers come from the modern side in the gymnasium which gives them no educational background in physics and chemistry

- very few "folkeskole" teachers have taken physics and chemistry as their special subjects and among these few women

- the students consider physics and chemistry as difficult, uninteresting and male subjects - why?

- students attending the gymnasium have very different experiences with physics

These comments are not to be seen as an attack on "folkeskole" teachers, but they are made to explain the problems we come across when beginning the education in the gymnasium.

Another great change in the gymnasium is that students don't use their exams the same way as they did 20 years ago. At that time many students attended advanced studies at e.g. the universities. This is not the case today. 1/3 attends courses of long duration, 1/3 attends medium duration studies and 1/3 short duration studies. More boys than girls apply for advanced studies. More girls than boys apply for educations with restricted admission, and therefore more girls than boys are turned down. Girls apply for a limited number of professions and with high rate of unemployment.

Beside these effects the society has seen an enormous change in the use of technology the last 20 years. It should not be necessary to give examples. As well introduction of modern technology as discussion about its possibilities and risks must be an integrated part of the education in the gymnasium. No doubt these subjects will find their way to the physics teaching.

These trends have been obvious for several years. The students on the science line (advanced maths and physics) make what is called specialities. These include about 40-50 lessons during 2'nd and 3'rd form of the gymnasium. In the 60-s these specialities were science-related (theory of relativity, further topics within nuclear physics etc.) This has changed much. Now typical subjects are related to technology and society (microelectronics, energyproblems, nuclear weapons etc.) Now the subjects must be exciting and of current interest rather than have the "smell" of fine science.

Also the methods of teaching physics have changed. The trend has changed from an orientation towards the physical disciplin and standard textbooks to an orientation towards topics dealing with society, technology, music, pictures of the physical world etc.This will also mean a change of the work in the laboratory . The choice of experimental methods and apparatus will be much more free and much more interesting and instructive for the students than the well known demonstrations of different physical laws. For some years an educational experiment along these lines has been carried out in physics/chemistry affecting 50% of the students on the social-science line of the science side with great succes.

The great change in society due to the introduction of computers and informationbased technology will have consequences for the education in science, and especially in physics. Experiments with this education have been carried out for several years. In physics Danish teachers have worked with computers both as an aid in computation and also as an object itself. Many classes have worked with microelectronics.

Starting this year all pupils in the 1'st form of the gymnasium will take a course of 30 lessons in the use of computers in modern society. The course includes three parts: programmes and machines, consequences for society and consequences for individuals. The education is not related to a single subject, but 3 teachers (science, socialscience or arts, language) are responsible together. In 2. and 3. form of the gymnasium the course is to be followed up in different subjects. Physics is included of course.

For these reasons, and a number of others, a further change in physics education is now necessary. FYSIKLÆRERFORENINGEN, physics teachers organization, has in coorporation with the physics inspectors from the Ministry of Education made a proposal for a new curriculum. This proposal has been discussed among physics teachers and other people concerned with physics during this winter and is now in it's final form handed over to the Ministry. It is our hope that the new curriculum can be tried out in many schools starting this autumn.

Many different aspects are included in a work with a new curriculum.

tradition

science computers

political realities society

textbooks new technology
every day technology

fads

pupils voices natural phenomenas
girls and physics
knowledge and astonishment

Physics is taught on 2 levels in the gymnasium. An A-level with 3-3-5 lessons a week for students on the science line (advanced math and physics) and a B-level with 3-2-2 lessons a week on the other lines in the science side. The curriculum in the 1'st of the gymnasium is common and includes mechanics (1-dimension), theory of heat, gasses and stationary currents. On both levels the subjects in 2'nd and 3'rd form of the gymnasium are mechanics (2-3 dimensional), electrical and magnetic fields, atomic and nuclear physics and wavemechanics.

The new curriculum will not change these topics much, but the form and goals for the education should change much.

The goals are for A-level (in short):

- a coherent understanding of central parts of classical and modern physics
- arranging and carrying out physical measurements
- mastering written exercises within a limited curriculum
- understanding the use of physics in technology and in other subjects

for B-level (in short):

- impact on the use of physics and physical methods
- a coherent understanding of selected topics within classical and modern physics
- carrying out measurements and calculations
- understanding the use of physics in technology and in other subjects

The organization of the teaching should be changed in accordance with the experiences from the educational experiments mentioned earlier.

- changing the starting point of the education from curriculum and textbooks to themes, which include prescibed topics. On B-level about 50% of the time should be spent on such themes

- a change from science to technology and it's use in society

- excursions, articles from newspapers and periodials etc. are recommended as a natural part of an education in physics

- adjustment of the written examinations as a consequence of the changes of the curriculum

- a change in the reporting from experiments in accordance with the intentions of more project-related teaching

Main changes in the curriculum are

- only common curriculum in the 1'st form for the individual school. Recommendation of 2 main subjects: energy and stationary currents with digital rounding and technical applications

- Mechanics is moved from 1'st to 3'rd form of the gymnasium , where the mathematical apparatus is at hand

- Wavemechanics is removed from both levels. A number of small but difficult topics: rigid bodies, alternating current, theory of relativity is removed from the A-level. At B-level the electromagnetic field theory should be treated phenomenologically

- on both levels the introduction of a new topic: "the physical world picture" of 10 to 20 lessons and "information-technology" of 10-20 lessons on A-level

We hope that these changes will solve many of the actual problems.

THEORY OF MATHEMATICS EDUCATION: RECENT DEVELOPMENTS AND MAJOR PROBLEMS

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1. Background and purposes

I appreciate greatly having this opportunity for presenting - at the Nordic Conference on Science and Technology Education - some remarks about the extensive development of *theory about mathematics education* which has taken place during the last three decades. As my title indicates, and as the programme of the conference implies, I can only deal with a few selected aspects of *recent* developments within this domain and point to some *major problems* with which the didacticians are faced in these years. However, I hope and believe that the ongoing development concerning theory of mathematics education on a longer view will serve to further co-ordination and co-operation between teachers of mathematics and teachers of science and technology.

This written account of my presentation must be about as brief as the oral formulation, since a more complete and detailed contribution - and most certainly any *analysis* of the aspects to which I am pointing - would fall without the framework of the Conference Proceedings. However, I shall provide references which will give access to the international debate of my theme, and let me in that connection emphasize that my remarks on the development of theory of mathematics education are given in an international perspective. My background for doing this is my own involvement in the international debate both as a participant and as a member of a large number of planning committees for meetings on didactical themes (thus the three latest world congresses on mathematics education) and as member of the Executive Committee of ICMI (the International Commission on Mathematical Instruction) since 1974.

Let me in these introductory remarks include a description of the context in which a world-wide debate about mathematics teaching and learning has taken place since the late nineteen fifties.

Mathematics has throughout the history of institutionalized education had a prominent place among the school subjects. Thus, the allotment of hours for the teaching of arithmetic and mathematics has traditionally been high and is even today - with the pressure from the increasing number of subjects for school teaching - only second to the number of hours allotted to the mother tongue. Some consequences of this must be mentioned:

(1) many outstanding philosophers, mathematicians, and mathematics teachers have - in the course of time - been motivated to, and obliged to, reflect deeply upon the overall aims and intentions of mathematics teaching and upon the ways in which mathematics is created (and discovered?) by the mathematician and acquired (discovered/created/constructed) by the learner;

(2) a very large part of the teacher population has - at all times - been actively engaged in the teaching of mathematics, and this has created a latent (but up to recent years seldomly exploited) potential for thinking about the teaching/learning process;

(3) the teaching of mathematics came to be considered as an important part of formal education and was traditionally ascribed value for the development of highly appreciated mental abilities (to work orderly and with precision, to systematize, to prove);

(4) the teaching of mathematics came traditionally to be used as a "screening subject" par excellence which meant that the student's performance at tests and examinations became decisive for his future placement within the educational system.

The features (1), (3) and (4) represent (in various textual forms) clearly a rich potential for reflections on didactical themes, e.g. for critical investigation of the "classical" questions about goals, contents, methods, and evaluation; reflections which were formerly *the privilege* of a few, personally motivated, mathematics teachers at the various educational levels, and *the obligation* of those involved in school administration or in the development of official decrees and descriptions concerning mathematics teaching. The feature (2) shows - as already mentioned - a rich potential for involving a large part of the active teachers in such didactical reflections.

The influences of the tendencies mentioned in (1)-(4) were part of the context in which the future of mathematics teaching was envisaged in the fifties. Wide ranging hopes and plans for educational innovation had been accumulating during the war and the succeeding years of economic difficulties. Both factors were at work when the international reform movement of mathematics teaching took its beginning in the late fifties.

The "first wave" of the reform (up to about 1966-67) resulted in considerable changes in the mathematical content of school teaching. The reform aimed at its outset at obtaining better co-ordination between the teaching of mathematics in the upper secondary school and at the university. But it spread - among other things due to the accumulated need for changes and adjustments of the traditional school system with its emphasis on and support of the "drill-and-practice-pattern" - rapidly from the upper secondary level to the intermediate levels, and also - with unfortunate side effects - to the primary level. The use of "the language of sets" was seen as a major means for the learners' attainment of an improved mathematical understanding: a *relational* understanding carried by an integral mental attitude towards mathematics. Accordingly, great priority was given in these years to the development of textbooks and teaching materials. However, it became widely recognized during the sixties and the early seventies that learning, in spite of the efforts to the contrary, remained predominantly instrumental.

But other ideas and tendencies were (as mentioned above) at work integrated in or parallel with the development just mentioned. Thus, it was increasingly advocated that not the teaching material, but the *teacher*, was the crucial factor in mediation of mathematics in school. And, at a later stage, a growing and related didactical interest was seen in the learners' working process during his *interaction* with the teacher. This development was due to several interrelated aspects linked to the strong socio-political movement away from an élitarian educational system towards a school structure in which mathematics was taught to all pupils from the first year of school. This movement towards "mathematics for all" led to an increased demand for building upon the students' experiences from practical work.

During the seventies, "mathematical activities" became a prominent topic in journals for teachers of mathematics. Reports were published on work in the classroom with tessellations, geoboards, dominoes, building with cubes, etc. etc., and analyses were made of the mathematical scope of each such activity. Normally, the stated purpose was to provide learners with opportunities for open, exploratory work - preferably in groups - on the materials and ideas in question. However, it was increasingly recognized that *doing* "mathematical" activities need not result in learning of shared mathematics.

And thus, the eighties have seen a recognization in the didactical debate of the teaching process as intentional on behalf of society and teacher and a growing interest in analyses of models under which the teacher may support and regulate the learner's activity in ways which promote that learning takes place *as intended*. Clearly, analyses and investigations of such models must take into consideration the complex interplay between cognitive and social aspects of mathematics teaching and learning in the setting of the classroom; and *theory* about these models must build upon contributions from several basic sciences, which can ensure that the model is considered in at least *mathematical*, *epistemological*, *cognitive*, and *social* perspectives.

2. Mathematics education as a process and as a discipline

The individual's learning of mathematics in the context of school takes place *in a process* in the course of time. And this is the case both for his construction of *personal* knowledge and skills and for his development of knowledge which is *shared* with others within and beyond the classroom. These learning processes are initiated, motivated, supported, guided, and controlled by the teacher. And here *the teaching of mathematics* may be conceived as a process of interaction between the teacher and the learners (individually or in groups), in which the teacher aims at the learners' acquisition of knowledge, skills, know-how, and attitudes in accordance with *predesigned* goals and intentions.

Learning and *teaching* are both *processes of change*. Thus, concepts, skills, and attitudes (already acquired or in acquisition) are continually subjected to reconstruction, adjustment, and further development in connection with the learner's growth and due to his work with mathematics in school. And the teaching process is planned according to - and provides for - these changes in the learners. Thus, the teacher aims at adjusting his functions according to the flow of the learning process.

School as an institution is a tool created by society with the purpose of providing access for the next generation to parts of the accumulated knowledge and know-how created by mankind and organized in domains, such as for instance the domain of mathematics. And school is also an instrument by which the socio-cultural norms are mediated to the learners in a process of socialization which is integrated in the teaching of the various school subjects. The teaching process in the classroom is, accordingly, guided and controlled by a number of social instruments, which serve to establish frames for the work of the teacher.

In the individual country, some of these social frames are based upon decisions made at governmental level or by educational authorities of different types. They may be called "external, societal frames for the teaching process", and they are often constituted by means of a set of official descriptions (e.g. concerning *goals*, *content*, *methods*, and *evaluation*) which stipulate "the official duties" of the teacher of a given school subject at a given level. Other external frames of a social nature are for example: the *textbooks* (which often serve to perpetuate traditional conceptions and norms); *collections of tasks* belonging to official tests and examinations; *systems of control*, e.g. performed by inspectors or advisors; and the *structure of school*, e.g. exploiting means such as *division according to ability* and *branching* aiming at the student's future education or occupation.

However, the work of the teacher in school is guided and controlled also by *internal* frames. Thus, the teacher's knowledge of mathematics, and to a very high extent *his conceptions of mathematics*, *teaching*, *and learning* serve as determinants for his interpretation of the official guidance and for his exploitation of the given structure of school. And the same counts for *his general attitudes*, *views*, *and principles* (which are, as the above mentioned conceptions, of a more or less conscious nature). Such internal determinants are developed by the individual teacher during his private and professional life, conditioned by the social settings of his environment.

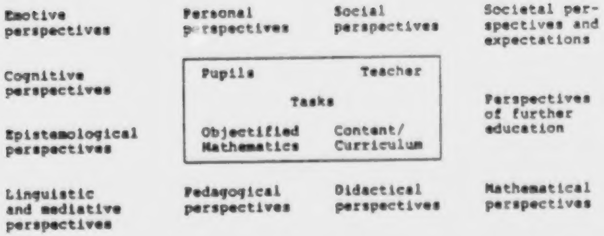
The internal frames just mentioned are of a *social* nature. Their impact on the teacher is of specific importance due to his fundamental roles in the teaching process. But the student and the parents are similarly conditioned by their socio-cultural environments. These social frames and norms are due to the prevailing conceptions within a society. They are formed in the course of time with roots back in the history of the society in question. They are in a sense decisive for what can be perceived and conceived, and what can be thought and done.

Accordingly, these social factors determine to a degree: how teacher and learner interact; how the teacher is influenced by his colleagues or by his superiors; how the teacher relates to parents in the society; and how parents - and the public at large - look upon school, learning, and mathematics. Important questions concerning the implementation of educational planning are linked to the influence of such "hidden" social frames, to which reference is often made by the terms "the hidden curriculum".

The above considerations are more or less direct quotes from an invited paper on "New Trends in Mathematics Education from a World-Wide Viewpoint" which I presented at the 1983 ICMI-JSME Regional Conference in Tokyo (Christiansen, 1983). I deal in that paper in further detail with mathematics education as a process in the classroom (i.e. *as a process in the small*) and in the manifold classrooms (i.e. *as a process in the large*). The framing factors to which I have just referred provide background for an identification of common patterns in the flow of the teaching process from classroom to classroom and for a tentative identification of tendencies in the changes of these patterns over time. And my task at the Tokyo Conference was to provide answers to the questions mentioned in this quotation from the paper (*ibid* p. 103):

> "The problem field for our consideration is the way in which the patterns in the flow of the teaching process (in the small or in the large) are changing. What are the changes in direction and intensity of the ongoing process? And which are the forces behind, and within, such changes? And, furthermore, what are the possibilities in the implementation of educational planning?"

At the present occasion, the above will serve to demonstrate the complexity of mathematics education as a process. Thus, the learner's construction of mathematical knowledge and know-how takes place under influence from factors which are clearly of *cognitive* nature (concerning the psychological aspects of the individual's acquisition, storage, and application of knowledge), of *epistemological* nature (concerning types and dimensions of knowledge), of *social* nature (as demonstrated), and of *subject-specific* nature (concerning the strong content- and object-orientation of human activity and learning). But my repeated emphasis on the four perspectives indicated here by my use of italics should not conceal that the mathematics teaching/learning process takes place under influence of a *multitude* of factors and that some of these in the individual case may be of specific and decisive importance for the quality of learning.


Emotive perspectives
Personal perspectives
Social perspectives
Societal perspectives and expectations
Cognitive perspectives
Pupils
Teacher
Tasks
Perspectives of further education
Epistemological perspectives
Objectified Mathematics
Content/ Curriculum
Linguistic and mediative perspectives
Pedagogical perspectives
Didactical perspectives
Mathematical perspectives

The rectangular core of this diagram illustrates the traditional *meeting place* for the minds of the teacher and his students: *the mathematical tasks set by the teacher*, and it illustrates, furthermore, the relational character of these tasks. Thus, the individual task is in principle posed because the student's activity on the task is seen as a means to promote his learning of mathematics in accordance with the demands inherent in the official curriculum/content of school mathematics; and these demands are again dialectically related to mathematics as an objectified body of knowledge and know-how created and accumulated by mankind in the course of history. The interaction between teacher and learners - during their activity on the task in question - provides the teacher with opportunities for mediating mathematical meaning and learning as intended. However, the dangerous catch in this is the widespread use of tasks (taken in textual forms from the textbook) as if the student's work on these tasks more or less automatically will result in learning as intended.

If a relational learning of mathematics is to be promoted, it seems to be highly necessary that the setting of tasks takes place in a number of contexts which are different from that of the textbook (in which standard-tasks are exemplified and cues as to meaning and procedure are "streamlining" the student's activity). Thus, to exemplify: tasks may be set in close relationship to the immediate environment of the students; they may be posed in relation to specific *ad hoc* domains chosen by the teacher with specific purposes in mind; and they may be constituted within project-work which necessitates an interplay between mathematics and other sciences or subjects. Such an approach would have to build on a conscious exploitation of the relationships between the tasks and the four other components mentioned in the rectangle of the diagram. This problem field is analysed and discussed in great detail in (Christiansen and Walther, 1985).

It follows from the above that the rectangular core of the diagram in itself represents an acceptance of a degree of complexity of the teaching/learning process which goes far beyond the dangerous reduction to the "triangle": *Teacher-Task-Students*, within which the widely used textbook-bound teaching of mathematics takes place. But, in addition, the diagram indicates a selection of important perspectives which are influencing the teacher's interaction with the learners during their activity on the tasks in question.

The development of mathematics education as a process in the classroom during the last three decades have been strongly condusive to a related study of the full problem field of mathematics teaching and learning in the complex context just indicated. This study - or this discipline - which is *about* mathematics teaching and learning, is known in Denmark as "Matematikkens didaktik", and it is named similarly in the other Scandinavian languages, and in German and French. The terms "the didactics of mathematics" have in Anglophone countries some unfortunate connotations. Hence, the study of the problem field of mathematics teaching and learning is often in these countries termed *mathematics education as a discipline*. I shall now look upon recent developments of that discipline, which may perhaps in the future come to be known also under the name "Theory of mathematics education".

3. Theory of Mathematics Education (TME)

The specific nature and character of the didactics of mathematics and the role and functions of this discipline were widely discussed already in the sixties. The debate was linked to - and strongly supported by - the accumulating knowledge and experience from the international reform movement of mathematics teaching, but it was also influenced by the strong socio-political endeavours to improve the educational systems in general. The interest in the *status* of the discipline was high. Thus, the term "the didactics of mathematics - an emerging science" was brought to the attention of the participants in the Second International Congress on Mathematical Education, the Exeter-Congress, in 1972 by Madame Krygowska, Poland, who used it in a questioning mode when visiting a large number of the fourty working groups of the Congress to give her views on important aspects of the discipline (Howson (ed.), 1973, p. 48).

This question about the discipline of mathematics education as a science was highlighted a few years later in an important series of papers on character and role of the didactics of mathematics (Steiner (ed.), 1974) published in *Zentralblatt für Didaktik der Mathematik*. Both Freudenthal and Otte dealt here (in contributions entitled respectively "Sinn und Bedeutung der Didaktik der Mathematik" and "Didaktik der Mathematik als Wissenschaft") with the relationships between theory and practice, but from very different positions.

Freudenthal (*ibid*, pp. 122-24) stated that observation of the learning process is the source of knowledge about mathematical education "als Lehre und Forschung". He proposed that if the didactics of mathematics shall at all be established as a science, the discipline must be developed from observation, investigation, and analysis of the learning process.

Otte (*ibid*, pp. 125-28) took the complexity of the field as his starting point. It is a complexity of critical situations comprizing urgent problems of the teaching practice which call for the use of scientific procedures, but also for immediate decisions. A complexity, which by its nature necessitates an interdisciplinary approach, and which can be handled only on the basis of theoretical knowledge *and* scientific processing of practical experience. Theory can develop means which can serve for orientation of practice. But since the complexity met in the practical situations goes beyond the scope of the theoretical abstractions aiming at their explanation, the practitioner must develop ability to estimate - and to cope constructively with - the differences and the relationships between the theoretical model and the real situation. However, the central part of Otte's paper was concerned with the constitution of the didactics of mathematics, or rather of its central object for study. He aimed at an identification which prepares for a unified conception of the social, psychological and mathematical aspects of mathematics teaching. I quote (from Christiansen, 1983) my own translation of Otte's 1974-characterization of the didactics of mathematics as a scientific discipline:

> "Mathematics education is realized through a number of co-operative partners and co-ordinated functions. The relationships between these are motivated, established, and organized in the perspectives of the mathematical content. The system of these relationships constitutes the central, scientific object for the didactics of mathematics when the optimization of the system is taken as a built-in condition for its establishment. Such relationships exist and are developed between teachers; between teachers and school administration; between teachers and scientists from the supporting disciplines (mathematics, pedagogy, psychology, etc.), and finally between these disciplines."

These papers by Freudenthal and Otte are of specific importance. They defined - in 1974 - new promising lines for the development of the didactics of mathematics into a scientific discipline, and both authors have in the succeeding years developed their ideas further in their own work and in groups of colleagues with whom they co-operate.

Thus, Freudenthal has in his "Didactical Phenomenology of Mathematical Structures" (published 1983 as the first volume in the Reidel Mathematics Education Library) provided us with an extensive, detailed, and illuminating description of his *didactical phenomenology*, which in my opinion will identify for many of us as teachers "the places where the learner might step into the learning process of mankind", to use the author's own words. And Otte has utilized *his* set of ideas about the systems-approach, about interdisciplinarity, and about the relationships between theory and practice in a number of projects at Institut für Didaktik der Mathematik, Universität Bielefeld, and in the BACOMET project (see section 5), and he has furthermore (Otte, 1984) extended his ideas in a more general setting and on the background of the most recent developments.

The major questions - and the lines of development - which have been indicated above are in my opinion of dominant importance for the future development of *mathematics education*. And this counts both, when this term refers to the educational process in the school, and when it refers to the discipline. We have to live and produce in the complexity of human, social interaction. And we must learn how to *teach in and with* this complexity. In our continuing efforts to meet these purposes, we must learn from observing and analysing the learning process. We need, however, scientific theory to be able to handle the complexity in our studies and research *and* to cope with the complexity in decision making in the classroom. And theory is also needed as a background for orientation in our reading, in our understanding, in our constructive activity, whether we are teachers, teachers for teachers, or didacticians deeply engaged in research and development work.

* * *

Let me insert here a few remarks about the important role played by Unesco (and especially by the Unesco Division of Science, Technical and Environmental Education) in the establishing of a network of contacts within the international community of mathematics educators, and - more specifically - in the planning and sponsoring of a long line of professional meetings on mathematical education during the decades considered here. Two features, both linked to the ICMEs (the International Congresses on Mathematical Education), may suffice as illustration.

The volumes I-III of the Unesco series "New Trends in Mathematics Teaching" were published by Unesco (1966, 1970, 1973) in various forms of close co-operation with ICMI (the International Commission on Mathematical Instruction). This influential co-operation resulted in 1974 in a request from Unesco that ICMI should take the full professional responsibility for Volume IV (1979) of the series. The editors of

"New Trends IV" (the then Vice-presidents of ICMI) have described the ensuing planning and the systematics used in the introduction to the volume which appeared in English, French, Spanish, and Japanese versions (Christiansen and Steiner, 1979). Let me recapitulate some major aspects here:

The authors of the volume were brought into a year-long co-operation initiated by a "plenary" meeting with the editors and invited specialists. The working process involved international advisory groups counting about 150 colleagues from some 40 countries and was influenced in its later stage by debates of the chapters in preliminary form at the Karlsruhe-Congress (ICME 3) in 1976. The outcome was a volume in which the total field of mathematics education is brought to the reader's attention. Thus, the titles of the chapters define a matrix, subdividing the field *according to levels* and *according to selected major educational themes*.

I venture to say - although I was co-responsible for the planning and development of the volume - that the process by which "New Trends IV" was established was an important event in the ongoing identification of the Discipline of Mathematics Education (or in my terms: the Didactics of Mathematics). The volume *in its totality* depicts in a balanced way the state in the early seventies of the process of mathematics education - *and* the state of the background discipline. And it conveys to the active and constructive reader *balanced estimates of trends* in the development both of the field of education and of the didactics of mathematics.

The growing consciousness about the problem field of mathematics teaching and learning in school (and to a lesser degree at universities) has been clearly demonstrated by the increasing attendance (in terms of the number of members and countries) at the world congresses on mathematics education. This is illustrated by the following table which must be considered in the perspective of the site of the congresses.

		Participants	Countries
ICME 1	Lyon 1969	655	42
ICME 2	Exeter 1972	1.384	73
ICME 3	Karlsruhe 1976	1.831	76
ICME 4	Berkeley 1980	2.100	80
ICME 5	Adelaide 1984	1.984	69
ICME 6	Budapest 1988		

The ICMEs are organized under the responsibility of ICMI, and the co-operation between ICMI and Unesco have here been of specific importance for the identification of professional contributions from developing countries. Moreover, educational divisions at Unesco have over the years provided valuable support for travel costs of mathematics educators from these countries in connection with planning meetings and congress participation. The line of congresses has served as a very important means for organization of the international debate of mathematics education as a discipline *and* for utilization of the latent potential for didactical debate mentioned in point (2) of section 1 above. And the same counts for a large number of related conferences convened in the periods between the congresses and often co-sponsored by ICMI and Unesco. The five Congress Proceedings, and the numerous reports from the special (often regional) conferences, have been one of the important driving forces behind a large number of national journals on mathematics teaching and learning. Several of these periodicals have obtained international recognition as highly specialized journals on the didactics of mathematics and serve as such to promote purposes which are well-known from the development of mathematics and the natural sciences: to identify *quality within the discipline*, to further *critical debate of issues*, and to support the *creation of new scientific knowledge*.

* * *

I have already pointed to the special role of the Karlsruhe-Congress for the debate of the nature of the didactics of mathematics. Let me now report about some programme events at the Adelaide Congress

(August 1984) which in my opinion will be of marked influence on the future development of the discipline.

A series of four sessions on "Theory of Mathematics Education (TME)" was organized at ICME 5 by Hans-Georg Steiner, IDM Bielefeld. The theme was treated through eight presentations with subsequent debates and these were continued in further depth and detail during a Post-Congress Conference on TME during the two days following immediately after the closing of the Congress. A report of the proceedings, including the presentations, has been published by IDM Bielefeld (Steiner et al., November 1984). In his introduction to this report, Steiner describes the overall intentions behind the organization of the meetings as follows:

> "The *main goals* of these two initial TME activities at Adelaide were to *exhibit and discuss the needs for*
>
> - identification of *basic problems* in the orientation, foundation, methodology, and organization of mathematics education as a discipline;
> - development of a *comprehensive approach* to mathematics education in its totality as an interactive system comprising research, development, and practice, i.e. for a *systems view* as a kind of self-applicable *meta-paradigm*.
> - *meta-research* related to mathematics education which on one hand should provide information and data about the situation, the problems, and needs of the discipline, respecting the considerable national and regional differences, and on the other hand should contribute to the development of meta-knowledge and a self-reflective attitude as a basis for the establishment and realization of TME related developmental programs.
>
> Furthermore it was hoped that first agreements could be reached on future work and actions to follow the two Adelaide activities."

Theory of Mathematics Education (TME) was in the structure of the congress seen as a Topic Area. The interest for this highly specialized theme was impressive. Thus, about a hundred members signed the list of attention (thereby indicating their wish to be kept informed about follow-up activities) and a core group of some seventy colleagues followed all sessions of the series and the Post-Congress Conference. At this it was agreed that significant progress in the dealing with the tasks delineated in the above quotation about the main goals had to build upon a "basis of *carefully planned and co-ordinated studies* and *specific conferences* on the one hand and *broad and open discussions* at a variety of national and international meetings with many people concerned on the other hand" (quoting Steiner's formulation in the report). A committee was established for the planning and organization of the coming TME-activities. As a first result, an international conference on "Foundations and Methodology of the Discipline of Mathematics Education (Didactics of Mathematics)" is convened in Bielefeld in July this year.

It was apparent at Adelaide that a tentative agreement is emerging in these years within a significant, international group of specialists who are active in research and teaching in the field of the didactics of mathematics. Let me on that recent background mention some important developments and the related problem areas (cf. the title of my paper).

The emerging, open agreement recognizes:

- the necessity of accepting the full complexity of mathematics education; and, correspondingly, that improved ways and means must be identified to cope with this complexity in theory and practice;
- the need for a comprehensive, systems oriented, interdisciplinary approach to mathematics education; and, correspondingly, that this integral body of theory must come to provide a generative support for development of explanatory systems and models dealing with specific aspects of theory and practice;
- the need for increased knowledge about knowledge, developed in epistemological, social, cognitive, and mathematical perspectives, and related to the dimensions of personal, shared (social), and objectified knowledge; and, correspondingly, that ways must be developed for using such meta-knowledge in the process of mediation between didactical theory and classroom practice;
- the necessity of becoming able to cope with the concept of complementarity and to exploit activity theory as an organizing principle in mathematics education as a discipline and as a process; and, correspondingly, that means must be found to cope with the difficulties of bringing these concepts to bear on teacher education.

The above serves to illustrate that the relationships between theory and practice constitute a major problem area for study and research.

4. The Theory/Practice Interface (TPI)

A series of four sessions (co-ordinated with the TME-series) was organized by me at ICME 5 on the theme "Systematic Co-operation between Theory and Practice in Mathematics Education". Eight colleagues (and among these the organizer) from six countries were centrally involved in the planning as contributors, and the series aimed at a first investigation of *case studies in which didactical theory is brought to interact with practice*. Also this series was followed by a core group, in this more specialized case consisting of about 35 colleagues, most of whom belonged to the core group attending the TME-series. A report of the proceedings will be published later this year (Christiansen (ed.), 1985).

The overall purpose of this series was to contribute to the exploration of frames, forms, and contents of systematic interaction between didactical theory and classroom practice, or - stated in terms of the *persons* involved - between *didactician and teacher*, *researcher and teacher* or (related to further eduation projects) *teacher educator and teacher*.

In my introduction of the series, I emphasized that didactical theory - due to its very nature - is concerned with the teaching/learning process in the classrooms, and that the flow of this process in consequence should - in varying degree - be conditioning and determining: (1) the *initiation* of research projects in mathematics education; (2) the research *process*; (3) the *evaluation* of the results; and (4) the *application or implementation* of these. But I also referred to the growing recognization of the specific difficulties in bringing theoretical knowledge to bear fruitfully on teachers' practice:

> "However, the relationships between theory and practice are of an indirect and complementary nature, which makes meditation between these domains impossible by straightforward, pragmatic means. Hence, there is an increasing interest in the identification of links between theory and practice which can be utilized and exploited through new and constructive forms of interaction and co-operation between the practitioner and the researcher."

Six case studies (in the contexts of five different countries) were presented and discussed during the three first sessions. The high importance of investigating the process of mediation of knowledge and know-how through interaction at the *personal* levels involved (cf. the illustration) were clearly recognized in the presentations and the debates.

RESEARCHER, DIDACTICIAN, TEACHER EDUCATOR
↕
TEACHER
↕
STUDENTS

The concluding debate in a panel of all speakers became accordingly concentrated on three major questions which had been treated more or less explicitly in the previous sessions:

(I) What is the role of didactical theory:
    (1) for the researcher in his interaction with the teacher?
    (2) for the teacher in his interaction with the students?

(II) What are the potentials of such "interactive" projects:
    (1) in teacher education (pre-, in-service, and further)?
    (2) in curriculum development?

(III) What may be feasible means to promote international co-operation within the field given by the theme of the mini-conference taken in the broad sense?

The group of eight colleagues mentioned has agreed to continue this co-operation, and an international meeting will be convened in 1986 aiming at a preliminary clarification of these and similar questions: What might be understood in the context of "Systematic co-operation between theory and practice" by the terms "theory", "practice", "systematic interaction" or "systematic co-operation"? Which are (based upon case studies) major types of, or models of, interaction between theory and practice, and how may this field of models be systematized? What might be fruitful forms of international, co-operative efforts? The purpose is a first clarification of structures for *future* investigation of such questions, and the conference also aims at ensuring relevant conditions for dealing with the Theory/Practice Interface (TPI) at ICME 6 in Budapest in 1988.

5. BACOMET - An example of international co-operation

Steiner's proposal (cf. the main goals of the TME activities quoted earlier) that the future development of *Theory of Mathematics Education* (in the sense of the didactics of mathematics) necessitates *meta-research* directed toward the discipline itself and its development (so-called *self-referent* research) became an important theme for debates at the TME-sessions. Personally, I have had the benefit of a long-term co-operation within a group of colleagues who came to consider its own development of *knowledge about knowledge* as a prominent object for investigation. Accordingly, the theme of my presentation at the TME-series was "The Theoretical Background of the Project BACOMET" (Christiansen, 1984).

BACOMET (Basic Components of Mathematics Education for Teachers) is an international research project in which fifteen mathematics educators from seven European countries and the U.S.A. (in the project's first stage, 1979-84) were engaged in co-operative efforts to identify components of the didactics of mathematics which - in the setting of teacher education - could be characterized as *fundamental*, *elementary*, *and exemplary*. The project was established in 1979 on invitation from A.G. Howson, Southampton, M. Otte, Bielefeld, and me. The three of us had been co-operating in the development of "New Trends in Mathematics Teaching", Volume IV, and we hoped that the experiences from the fruitful long-term co-operation within the group of authors and editors of that volume could be exploited in the new project.

In the early years of BACOMET high priority was given to an investigation of the relationships between the evolving process and the intended products, and *a protocol for self-education* (for educating the group by the group) became then established. A major result of the process was to be a survey volume describing and analysing such *basic components*. The target audience should be the international group of teacher educators, but the organizing principle should be *the situation and needs of the teacher-to-be*, although not in a direct, empirical sense. On the contrary, *theoretical investigations of what is practice* had to be performed to ensure a deeper and more general value of the volume. Systematic attempts were made at using the major difficulties in the BACOMET working process as vehicles for constructive development, and this principle came to bear on the following problem areas: (1) to exploit the differences in knowledge and know-how within the group, and to proceed from the specificity of personal knowledge to shared knowledge; (2) to identify and develop knowledge which is appropriate for action; (3) to exploit principles and hypotheses which are simultaneously the objects for analysis and development; (4) to investigate the limitations and potentials of textual materials.

Knowledge about knowledge became a dominant perspective in the working process and in the development of the chapters of the BACOMET volume (Christiansen, Howson, and Otte (eds.), 1985). Thus, it was felt to be important to distinguish between the two complementary categories of knowledge: *specific information* and *overall awareness* as well as between different *levels of knowledge*. These distinctions are important for the teacher in his support of the student's construction of *shared knowledge* from *personal knowledge* and of the student's access to *objectified knowledge*.

As it is seen from these indications, BACOMET was in its first stage deeply concerned with the relationships between theory and practice. I exemplified this in my TME-presentation by means of the chapter on "Task and Activity" which was developed by Gerd Walther (Kiel) and me in co-operation with the full BACOMET group. The interested reader will see in (Christiansen, 1984) or - in further detail - in the BACOMET volume how *activity theory* is exploited as a teacher's tool for organization of the mathematics teaching-learning process in the classroom.

The model of international co-operation which was developed and exploited by BACOMET, and which is described in details in (Christiansen, 1984), is now in use in the second stage of BACOMET. I hope and expect that it will be utilized also in sub-groups to be created "within" the two related topic areas: TME (Theory of Mathematics Education) and TPI (Theory/Practice Interface). It is a basic feature of the model that the relationships between *personal*, *shared*, and *objectified* knowledge within a group of peers are exploited as a rich dialectical potential for creating new knowledge of each kind. Therefore, the working model of BACOMET may become a useful means for investigation of complex problem fields (such as, for instance, the didactics of the natural sciences) in which contributions are needed from a number of *different* basic domains of knowledge and experience.

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UNESCO'S ACTIVITIES IN SCIENCE AND TECHNOLOGY EDUCATION

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I am very happy to be present at what is, I understand, the first Conference convened in the Nordic Countries in recent years to exchange information on and discuss issues critical for the future development of science and technology education. This is also one of the first activities to be held in the framework of Unesco's International Network for Information in Science and Technology Education This network which was established as part of Unesco's current biennial programme includes institutions from over 100 Member States of Unesco as well as a number of international and regional non-governmental associations. Its purpose is not only to promote exchange of information among participating institutions on the current issues of science and technology education but also to encourage those with similar concerns to work together. It is also hoped that each institution will make the work of Unesco, in science and technology education, including the various publications in this field better known in each country. The network publishes a quarterly Information Note and has also launched a publication 'Innovation in Science Education' which will appear once every two years. I hope that, by the end of the Conference it will have been possible to formulate plans for some future activities on a co-operative basis.

I should like to say a brief word about Unesco's programme in science and technology education. What I shall say will, particularly, be from the standpoint of the Education Sector. My colleagues from the Science Sector and from the International Bureau of Education have already told you something of their work in science and technology education.

During this Conference I have noted with interest that there is a considerable correspondence between the topics we have been discussing here and the activities which Unesco is currently undertaking. Our activities are broadly of two types which are complementary. The first are concerned with overall improvements in science and technology education, and the second are directed to the specific fields of the teaching of physics, chemistry, biology and mathematics, to integrated science and technology education, and to education in regard to nutrition and health. Each of these types of activities may be international in nature, covering countries in all parts of the world, or regional - covering countries in one of the major regions: Africa, Arab States, Asia, Europe and Latin America. It also may be carried out in co-operation with one particular Member State or with a group of several countries.

An example of a general activity on an international basis was the holding of an international congress on the subject of 'Science and Technology Education and National Development' in 1981, attended by participants from over 80 countries from all parts of the world. The contribution which science and technology education can make to national development was examined by the congress, and strategies were formulated for the improvement of science and technology education in relation to development. A report of the Congress was published, incorporating suggestions for future action addressed both to Member States and to Unesco. A book based on the proceedings of the Congress has recently been published by Unesco. An international survey on the amount of time devoted to the teaching of science at the various stages of teaching is also presently being conducted, to be followed by in-depth studies in a number of countries.

In undertaking such international activities, Unesco works closely with international non-governmental organisations such as the Committee on the Teaching of Science of the International Council of Scientific Unions and the International Council of Associations for Science Education (ICASE).

At the regional level, an Asian meeting on 'Science for All' was held in Thailand during 1983. It was attended by participants from about 20 countries in Asia and addressed the issue that science is of value for everyone in all communities and societies. Ways were sought of providing everyone with scientific competencies, knowledge and skills appropriate to their immediate needs. This implies a much broader approach to science education than that of the formal education system. The meeting considered that more attention should be given to science education in non-formal education and to the use of the media for dissemination of scientific knowledge to the general public.

Other programmes have also been developed at the regional level, particularly to promote the exchange of ideas and information. These include regional newsletters, preparation and dissemination of documents on science education, and provision of study grants and travelling fellowships to enable key science educators to visit other countries. In Latin America a project to exchange information about production of low-cost school science equipment has been launched.

To encourage innovative approaches, experimental and pilot projects have been launched. In these projects, institutions in 4 or 5 countries have participated - usually countries in the same geographical regions or with the same language. Projects are currently in operation on the following topics: the use of calculating machines and computers in the teaching of science and mathematics; the teaching of science and technology in an interdisciplinary context - a project in which Denmark is a member; the use of educational games for teaching science to children; the preparation of innovative programmes for the training of science teachers by the media; and science and technology education and productive work.

Unesco has also given considerable support to out-of-school science and technology education activities such as science clubs, fairs, camps, olympiads, journals etc. It works closely with the International

Co-ordinating Committee for the Presentation of Science and the Development of Out-of-School Scientific Activities (ICC) to promote such activities internationally and regionally.

The second type of activities to which I referred are those directed to the teaching of specific disciplines. Within the teaching of physics, chemistry, biology and mathematics, Unesco's activities have been principally concerned with exchange of ideas and information about recent developments in each respective field. These activities have included preparation of publications - in particular the series 'New Trends in the Teaching of the Basic Sciences'. They have also included the holding of meetings on specific topics. These activities have been carried out in close liaison with relevant international non-governmental organizations. In chemistry, for example, Unesco works with the Committee on the Teaching of Chemistry of the International Union of Pure and Applied Chemistry. Every two years, this organization holds an international Conference on chemistry education and Unesco provides professional and financial support for the holding of these meetings.

Resource materials for teachers and for the up-dating of curricula have also been prepared, including source-books and hand-books of various kinds. A publication 'Studies in Mathematics Education' issued at regular intervals provides up-to-date information on world-wide trends in this field. National groups such as science teaching centres and science teachers associations have also been provided with professional and financial resources for developing their own science curricula and producing teaching materials.

The programme in integrated science education was launched some 15 years ago in response to the need expressed by many Member States to receive Unesco's assistance in designing curricula related to the interests and environment of young children. Unesco's programme did not attempt to identify one approach to integrated science education as 'the best' but sought rather to elaborate various approaches and curriculum 'models'. It also sought to encourage the establishment of working groups in Member States to develop, and subsequently implement, the model or models most appropriate to each country's own particular needs. The programme has produced a series of publications, it has supported the holding of three major international conferences and many smaller meetings and workshops. It has also provided technical assistance and services of various kinds for the development of integrated science curricula in many countries.

The activities to which I have so far referred are all funded under Unesco's own programme funds - known as the 'Regular Programme'. Unesco also plans and administers projects using funds from other sources such as the United Nations Development Programme. Such projects, in science and technology education, are often institutional in nature. They include, for example, the establishment of school science equipment centres, science curriculum centres and science teacher training institutions.

OBSERVATIONS AND REFLECTIONS ON EVERY-DAY CHEMICAL PHENOMENA IN INTRODUCTORY CHEMISTY. FORMATION AND USE OF A COMMON MINIMAL BASE

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Introduction

The project to be discussed is an introductory course in chemistry for the gymnasium ~ high school = upper secondary level. The course is expected to cover two weakly lessons from the schoolstart in the beginning of August to the middle of November (~ 20 lessons).

The course starts at a zero level and it is attempted to take advantage of the narcissistic trends and concrete thinking, described in the contribution by Jens Josephsen.

Aim

The primary goal is to introduce chemistry as a powerful tool to understand every-day experiences and hence to show that chemistry is relevant and a fundamental part of general education.

The course also aims at encouraging the students to investigate every-day chemical phenomena, to sharpen their observations and to increase the understanding of the relationships between chemical structure, physical properties and appearence.

Background

The different cultural backgrounds encountered in a "gymnasie" class just starting create a problem when selecting appropriate examples. The idea in this introductory course is to use what is called a "minimal knowledge basis" based on every-day experience.

Another reason for doing so is the general dwindling real world experience among students,as more and more of their time is spent watching television, playing electronic games, manipulating computers, listening to walkmen and spending time in discos.

Common basis

Consequently this allows only very few common chemical compounds. These comprise in our case: Water, sodium chloride, potassium nitrate, ammonia, sugar, lime, acetic acid, nitrogen, oxygen and carbondioxide. These compounds are referred to again and again and act as references. All other examples chosen have a strong connection to the private sphere: Coffee, tea, liquorice, mineral water, milk, butter, oil, petrol, soap, grease, alkohol, soft drinks etc.

Content

The choice of compounds makes"home studies" attractive. What is the pH of coke?, What is the content of disinfectants? etc.

A wide variety of techniques and principles can also be demonstrated by means of these simple and well known compounds and methods. Extraction and filtration are related to coffee- and tea-making. Solubility is related to dissolution of sugar in coffee, freezedrying to drying clothes below zero etc. By using these well known things the aim is a transfer of latent knowledge into explicit chemical knowledge and to give the students self confidence by showing that what they "know" is relevant.

A further aim is to make the students familiar with every-day chemicals so that these are not considered only as objects to be bought, consumed and discarded. By understanding the chemical background, the resigned feeling of living in an alien world hopefully disappears. This familiarity may also lead to a confidence so that the student finds it natural to probe into every-day phenomena.

Practical exercises and demonstrations clearly have a very dominant role in this introductory course. To encourage observations using both the olfactory sense and the vision examples with pleasant smells and bright colours are included. Such compounds are included also to increase the hitherto small array of compounds. Examples are food colours and artificial flavours. These leads into food and food technology, food additives and food quality control. Subjects such as food preservation make an opening towards biology and biochemistry possible.

The repeated use of a small number of well known and simple compounds from the students own world makesit possible to "label" chemical principles and hence to draw parallel and inductive conclusions.

ionic	t.o.	sodium chloride
hydrophilic	t.o.	water
solubility	t.o.	sugar
high melting pont	t.o.	sodium chloride
acid	t.o.	acetic acid
base	t.o.	calcium hydroxide
inert	t.o.	nitrogen

t.o. = think of

The understanding of the basic chemical principles for every-day chemical compounds and principles leads naturally into a discussion of technological methods and consequences.

To place the essential compounds in a broader context interdisciplinary essays are included. Geographical occurrence, form found in nature, industrial production, quantity, way of extraction or production, economic and ecologic importance, every-day use, and biological implications are treated.

The project described is a joint project with Jens Josephsen.

THERMOPHYSICS AT LOWER SECONDARY SCHOOL
AN EMPIRICAL INQUIRY OF PUPILS' CONCEPTIONS OF FUNDAMENTAL CONCEPTS IN THERMOPHYSICS

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Introduction

The purpose of this project is to document different kinds of ideas that lower secondary school pupils have about fundamental concepts of thermophysics. It is hoped that the project will give insight into the ways in which pupils conceptualise various phenomena and that this information can be useful in teaching physics.

Pupils are not empty buckets teachers can fill with knowledge. They come to the classroom with preconceived ideas based on their past experiences and conceptions of the world. Teachers have to take this "initial state" into consideration when presenting new information to reach a desired teaching aim. They must also be aware of the way pupils are thinking when they are constructing their own knowledge.

Such a constructive view on learning influences the methodology used in the project.

Methods

Both quantitatiave and qualitative methods will be used.

Quantitative data analysis:

The Second International Science Study (SISS) - a survey of three pupil populations. The items chosen are of multiple choice format. Only items concerning thermophysics asked to ninth graders will be examined to determine pupils initial state of understanding.

Qualitative data analysis:

Interviews will be conducted with pupils at the lower secondary level. They will be"discussions" related to an experiment. The experiments used in the interview situation will deal with phenomena of thermophysics, for example how a thermometer works.

The thesis is scheduled for completion in autumn, 1985.

BIOTECHNOLOGY TEACHING IN GRADES 8 TO 10.

DIDACTIC CONSIDERATIONS

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Introduction

Flemming Libner, the National Innovative Centre for General Education, Grades 8 to 10, Copenhagen, and I have since 1983 been working on materials intended to be used in connection with teaching modern biotechnology in 8th to 10th grade. The material, which includes teacher's guide, illustrating material and proposals for activities, will together with some of the results derived from testing in schools be more closely described by Libner in the following paper, while I here shall give the background for the choice of topic and some reflections on the ultimate aims of teaching the topic.

The production of the material has been subdivided into three stages. The first stage consisted in preparation of a preliminary first edition of the material and its testing in 1983/84 in a few classes at the Innovative Centre by teachers without biological qualifications acquired during their professional training in the teachers' colleges.

The second stage consisted in correction and change of the material on the basis of gained experience and testing in several schools in 1984/85. This second and still preliminary edition of the material is exhibited here at the conference.

The third stage will be the elaboration of a final edition, available to schools all over the country, adjusted in accordance with the evaluation of the second edition.

The social importance of biotechnology.

Biotechnology is as old as the use of medicinal plants, fermentation, and improvement of domesticated animals. Modern biotechnology includes sophisticated and direct ways to change the most intimate properties of living organisms and whole species: in-vitro-fertilization of eggs of mammals, screening of genes, genetic engineering, and cloning.

The near future will increasingly bear the stamp of technical exploitation of biological research results, especially within genetics. It is no longer an exciting field only to specialists, but a field of essential importance to all citizens, as the consequences will affect the individual's everyday life and the whole society.

It is important to expectant parents, to consumers of drugs and other industrial products, to people who shall make the political decisions with regard to guidelines in scientific research, trade policy, policy of health and medical care, environmental management, and - generally - long-term planning of human intervention into the conditions of life on our planet. The fundamental problem is the question how far mankind will dare to go.

It is important to democracy that the individual citizen is qualified to estimate the consequences of actions influencing social changes and everyday life and to come to decisions as to such actions on the basis of information and responsibility.

The demands on the individual citizen.

This is difficult with regard to the changes caused by the new biotechnology because pupils and many teachers and other adults have little or no knowledge of recent conquests in the fields of genetics and medical science. Many of them are not even aware of the probability that the consequences will be of personal concern to themselves and the fact that biotechnology is going to change social life and standards.

Those who are aware of it often believe that these matters are far too difficult to be understood by "plain people".

Such attitudes easily result in passivity. The individual will abandon any effort to keep up with the times within this important field, and this is a menace to democracy.

The individual may in case of her or his attention to the problems choose an attitude without shades, for or against science or the use of science, if insight in the problems is absent. This is also an unsatisfactory situation.

The choice of attitude and action ought to be based upon ethical considerations, but that is not enough.

New technique will bring both advantages and disadvantages, and a certain amount of knowledge of these is required if optimal decisions shall be taken. A cautious and restrictive attitude due to ignorance involves the risk of loss of advantages which may result in disadvantages outnumbering the feared ones. Blindness to the dangers connected with some kind of technique, on the other hand, is alarming.

The citizen must have a certain insight to be able to evaluate the probability, the quantity, and the quality of the consequences and know how to gain further information as a prerequisite for evaluation in particular situations. Training in evaluation of own altitudes is needed. To generalize conclusions from superficial knowledge of complicated issues may be useless or even dangerous.

Debates on surrogate mothers, production of bacteria or tissue cultures with human genes or genes for resistance against antibiotica, eugenics, and studies on the early stages of the human embryo cannot lead to a general refusal or a general acceptance of techniques because the concrete situations are different from each other and because the conditions, the methods, the measures, and the importance of advantages and disadvantages are variable. One's attitude may for instance depend on personal involvement as a patient or a parent. The understanding of these issues as being complicated is important, so the subject ought to be taught in the upper school classes, in connection with biology as well as social studies.

Some consequences of such techniques as genetic engineering and cloning are impossible to be understood by biologically ignorant persons. Postulated evolutionary risks cannot be evaluated, not even viewed as problems, by persons without biological training.

The appropriate teaching

It is necessary, for these reasons, that the children learn about biotechnology before they leave school, so that they get

1) an insight in essential results of genetics and adjacent branches of life science, and their application.

2) an understanding of the complicated nature of the consequences through experience in viewing concrete cases from different sides.

3) the conditions of ability to keep up to date after school, in acknowledgement of responsibility and the necessity of an independent, personal attitude based upon both knowledge and ethics.

By means of the teacher's guide included in the mentioned material we hope to uncover the professional problems in such a way that the teachers will not - from the outset - give up to treat them. It has been difficult to decide how far we should go into purely biological issues. We have tried to give the necessary, but not more than sufficient contents.

Teaching by means of the material is aimed at imparting to the children the realization that the subject is of interest and personal concern to them, the fundamental knowledge of the genetic code and various techniques, and some experience in judging statements dealing with advantages and disadvantages connected with such techniques.

SCIENCE EDUCATION AT THE SECONDARY LEVEL AS A PREPARATION FOR FURTHER STUDIES

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It is not possible in fifteen minutes to cover all aspects of the question: Why and how do we teach science in school? I shall only deal with the question of science education at the secondary level as a preparation for further studies. By the "secondary level" is meant the "Gymnasium" (= Grammar School, age 16-19).

Forty years ago about 2% of young people went through the science line of the Gymnasium. Major subjects were mathematics and physics, minor subjects chemistry and biology. I shall use the designations A-level (4-6 weekly lessons, written (physics only from 1966) and oral examinations) and B-level (2 weekly lessons, oral examination). The teaching of physics was characterized by the use of applied mathematics, but it also comprised a good deal of experimental work. In chemistry you memorized facts and did very little experimental work. Biology was mostly descriptive. Chemistry and physics were minor editions of the university courses, and you did not try to motivate the students. This was not necessary, as they were already motivated, because most of them wanted to go on to the technical university or other higher education.

In the following years the great influx of students began, and to-day the Gymnasium receives more than 20% of all young people as science students. Only a minority will go on with further science education, so a problem arose: many students did not feel motivated and found the teaching of physics and chemistry uninteresting (for some curious reason mathematics seems to be accepted by everybody and its importance is never questioned). A new Gymnasium with theoretical and practical lines would have been indicated, but for economical and political reasons such a reform was postponed. Instead we tried to adapt the Gymnasium to the new conditions. A biology line was established with biology on A-level, physics and chemistry on B-level, and mathematics on a level in between. The contents of the courses were adjusted little by little, especially in chemistry, where both contents and methods were changed. New textbooks attached more weight to general chemistry, while the knowledge of chemical compounds should be acquired mostly from experimental work. In 1971 it was recommended to spend about 50% of the time available on experiments. In order to motivate the students you should also emphasize the uses of chemistry, in industry and in daily life. Experimental work requires time, and with so few lessons it seemed impossible to fulfil these good intentions. Therefore it became more and more necessary to establish chemistry as a major subject on A-level. From 1972 the mathematics-chemistry line started at a number of schools as a trial. Mathematics is retained on A-level, but chemistry takes the place of physics. This chemistry line has been adjusted in different ways, and to-day it can be regarded as a permanent institution and can be established at every school without formalities.

This means that to-day you can become a science student in three ways:

	A-level		B-level
mF-line	math., phys.		chem., biol.
mN-line	biology	(math.)	phys., chem.
mK-line	math., chem.		phys., biol.

From all lines you can go on to higher science educations, only in some cases you must supplement with courses in your B-level subjects.

What happens now when the students have to make their choice between the three possibilities? If you want to go to the technical university you will choose the mF-line. If you have a special interest in chemistry the mK-line is an equal possibility. The mK-students have turned out to be just as successful as the mF-students. It is important to master mathematics on the high level, and it is important to have had either physics or chemistry on a high level, but it is less important which of them you have chosen. In both cases you get a training in problem solving as a preparation for the written examination. (By problem solving I do not mean arithmetical calculations, but thinking and reasoning and shaping of mathematical models.) Perhaps chemistry has after all advantages to physics. In physics there is a risk that you will work with standard problems and be trained in using the right mathematical formulas. At the examination you will ask yourself: which formula should I use here? - and if you are lucky you may succeed without understanding the problem fully. For the solution of problems in chemistry a deep understanding is often very essential, first of all a thorough knowledge about and understanding of the mole concept and its uses.

The student who wants to become a doctor of medicine, a biologist, a pharmacist, etc. will perhaps choose the mN-line. It has turned out that those students are less well prepared for a higher education, because they have had no basic science subject on A-level. Møller Jørgensen (ref. 1) has made an investigation of the performance of students of medicine at university examinations in mathematics, physics and chemistry and shows that mF-students (mK-students were rare at that time) obtain much better results than mN-students. These have spent much time in the biology laboratory and have acquired laboratory skill (and no doubt this has been motivating and exciting), but they have not got the deep understanding of the basic sciences, which you acquire partly through problem solving. This understanding is so necessary in further studies (not only on the highest levels), and you will find it difficult to obtain it at a later time.

It has to be admitted that perhaps the average mN-student is not quite up to the standard of the mF- or mK-student, because some students will choose the mN-line for negative reasons: they have difficulties with mathematics and physics and try to get away from these subjects instead of making a positive choice towards biology.

When students realized that the mF- (and mK-) line gave them the best possibilities more students would choose this line, also some students of lesser ability. So a demand arose that the teaching should pay regard to these students and be more varied, more entertaining and not require too much from the students. It should contain much experimental work, visits to industries, optional subjects, etc. The textbooks should be more inviting: different colours, many illustrations to please the eye. All this sounds very well, of course, and variation in your teaching is a good and more or less necessary thing. But it must not lead to a waste of time for the already motivated students, those who are going to carry on with the sciences on a high level. They should use the limited time in the most economic way to obtain a deep understanding of the subjects and a thorough training in problem solving.

I believe, however, that it will be of great value also to students who are not going to become scientists themselves that the teaching at school is done in a serious way, even if this may make it a little more "dull". It is at the Gymnasium that they should learn that every education requires hard work. In television they are watching a lot of entertaining and colourful popular science. It is all right if the school shows them something different. They should learn that a textbook can be very fine and valuable even if it appears to be dull. In the higher educations they will meet such textbooks.

I am not saying, of course, that you should consciously make your teaching boring and dull. With the sciences this will hardly be possible. They are exciting in themselves! To solve a mathematical problem, an analytical problem in chemistry or to carry out an experiment is exciting. Variation in the teaching is always good, and the teacher can obtain that also by adding information about the history of science, practical applications in industry and in daily life, etc. But the main purpose is still that the students acquire a deep understanding and a thorough knowledge of the subject. It is very well that the students are trained in the chemical laboratory and learn about the equipment, but laboratory work is time-consuming and must not be exaggerated. You can always be trained in laboratory practise later, but if you do not get a thorough training in problem solving as a young student it is very difficult or impossible to obtain it later. Experimental work can be combined with problem solving (quantitative experiments with calculations and reports), but qualitative experiments where you just observe that something is happening must not take too much time. Ring, the author of the first modern chemistry textbook for Danish schools, wrote in his preface: "Of course it is not the amount of experiments that counts. The main thing is that a desire for investigating and getting to the bottom of a problem is awakened in the students." (ref. 2).

My conclusion is that in our eagerness to motivate the students (unfortunately sometimes nowadays understood as "entertain the students") we must not forget that the main purpose is that they arrive at a thorough understanding of the subject and its concepts, so that they will remember it and be able to use it afterwards. Science teaching in the Gymnasium should contain many elements, but one of the most important is problem solving, which forces the student to get to the bottom of things.

It would be easier if the Gymnasium were still only a preparation for university studies. Then we could go further and say with the Dansih chemist K.A. Jensen: "Teach them mathematics and languages at school, and let me teach them chemistry at the university." It is no longer so, at all school levels we must also give science education to the average student as a future member of society. Everybody will see to that when in the next few years we shall be planning a new Gymnasium. It is to be hoped that somebody will also remember the good students and their needs.

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INTERDISCIPLINARY ENVIRONMENTAL EDUCATION

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Introduction

From Russia to Aarhus

The UNESCO intergovernmental conference on environmental education, Tblisi 1977, recommends to the member states: "To encourage the acceptance of the fact that, besides subject-oriented environmental education, interdisciplinary treatment of basic problems of interrelationships between people and their environment is necessary for students in all fields, not only natural and technical sciences but also social sciences and arts, because the relationships between nature, technology and society mark and determine the development of society". The Danish Ministry of Education has via a Nordic reference board for environmental teaching at university level tried to encourage Nordic universities to meet this challenge. In 1984 two Danish broadly interdisciplinary courses were started as an experiment for two years, one at Aarhus University and one joint course for institutions of higher education in Copenhagen. The experiences from Aarhus include the problems arising, when you intend to organize interdisciplinary teaching at an institution with strong traditions for single disciplinary (faculty) teaching, administration, and government grants.

Basic conditions

There are some essential basic conditions for establishment of an interdisciplinary course.

First of all the teachers must be strongly motivated because the demands to professional challenge, cooperation, coordination, and resistance to

conflicts are explicit. In Aarhus there were teachers with experiences in single-disciplinary environmental teaching, who wanted to supply their knowledge with other professionals.
Secondly, the students must be interested in substituting a professional with an interdisciplinary course. A group of students had worked seriously with environmental teaching and research resulting in the foundation of a Human Ecology Center at the university.
Thirdly, the labour market must be interested in the skills obtained at this course compared to normal graduate qualifications. Advertisement research showed that there was agreement between the plans for the course and the demands from the Danish environmental sector (public and private).
At last the special financial support necessary to release the course committee from economic negociations with the faculties and to understate the interest in the course. A University Fund is the owner of the factory Cheminova with a dubious reputation in environmental care. In 1984 the University Fund supported a two-year experiment with an interdisciplinary course.

Description of the course

The extent of the course is a half year full-time study within a one year period. Course applicants with at least a bachelor degree are qualified. The course is also offered as postgraduate education. The number of participants are 24.
The aim of the course is that the students shall learn to coordinate and become familiar with different professionals ability to identify, analyze, describe and propose or choose between alternative solutions to environmental problems.
The teaching plan is divided in sections: Natural sciences (biology, geology, chemistry). Humanistic sciences (philosophy). Medicine. Social sciences (geography, economics, law). The interdisciplinarity is obtained by relating the teaching to cases: Eutrophy in two selected freshwater systems. Extensive agriculture as origin to nitrogen contamination. In the last part of the course, the activities are concentrated on the students elaboration of projects. In casu: Air pollution and Danish agriculture in the future.

Excursions and guest lecturers with practical experience are important elements in the course.

Experiences and the future

We are now at the end of the first course and all the problems that could be foreseen have appeared. Too many teachers with too high ambitions with their topics calling for additional professionals to present other research interests. Personal conflicts for the student being forced for the first time to explain his topic to nonprofessionals. In spite or perhaps because of a high conflict level, there is no doubt that the course has fulfilled its aim, even though it may be characterized as a multi-interdisciplinary course. We are now planning the curriculum for next year with more relaxed attitudes and matured to make a better integration of the subjects. We have also realized that there must be a course for postgraduates and one for masters degree students. If the course shall continue after the two-year period, the financial problem must be solved and the course administration must be brought in harmony with the university administration.

TEACHING BIOTECHNOLOGY

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During the seventies and the eighties technology has played an increasing role as a teaching subject in the secondary schools of Denmark. The reason for this is obviously related to the pressure from the environmental and economical crisis of the Western World. The rapid increase in existing technology and the expansion of "new technologies" call for rapid changes in the fields of education.

This paper will concentrate on the possibilities and problems of teaching technology in biology at the secondary school level. I want to emphasize that technology-teaching should be interdisciplinary, but that the structure of the Danish school system in general makes this impossible.

After a short introduction of biology-teaching in Denmark, a theoretical frame for technology-teaching is presented and exemplified with experiences from biology-teaching. Finally some prospects for incorporating technology-teaching in the future are elaborated.

Biology-teaching in the secondary school of Denmark.

In Denmark biology is taught at two levels in the secondary schools, the lower level having three weekly lessons in the final schoolyear (3rd gymnasieklasse), the higher level ten weekly lessons distributed over the last two years of school (3 weekly lessons in the 2nd gymnasieklasse and 7 in the 3rd). At both levels the purpose of the education is to "improve the student's ability to formulate and solve biological problems" and to "comprehend biological methods and reasoning in a critical and analytical manner" and furthermore to "use biological knowledge and methods on individual as well as social problems".

The curriculum is not described in every detail which gives the students and teacher a choice of subject within certain frames. This is the basis for making the lessons more thematic and coherent, using concrete examples of general phenomenas. In this view the technological advances in agriculture, fishery, food-production, and waste-treatment obviously are important subjects of biology-teaching. During the last years the rapidly expanding biotechnologies in production as well as in reproduction play an increasing role in teaching.

A theoretical frame.

In order to plan a qualified instruction in technology it is necessary to have a good frame of understanding. I find the model presented in figure 1 suitable for several reasons: i. it places technological improvements in different sections of the production process (i.e. objects of labour, means of labour, and labour power), ii. the model does not only focus

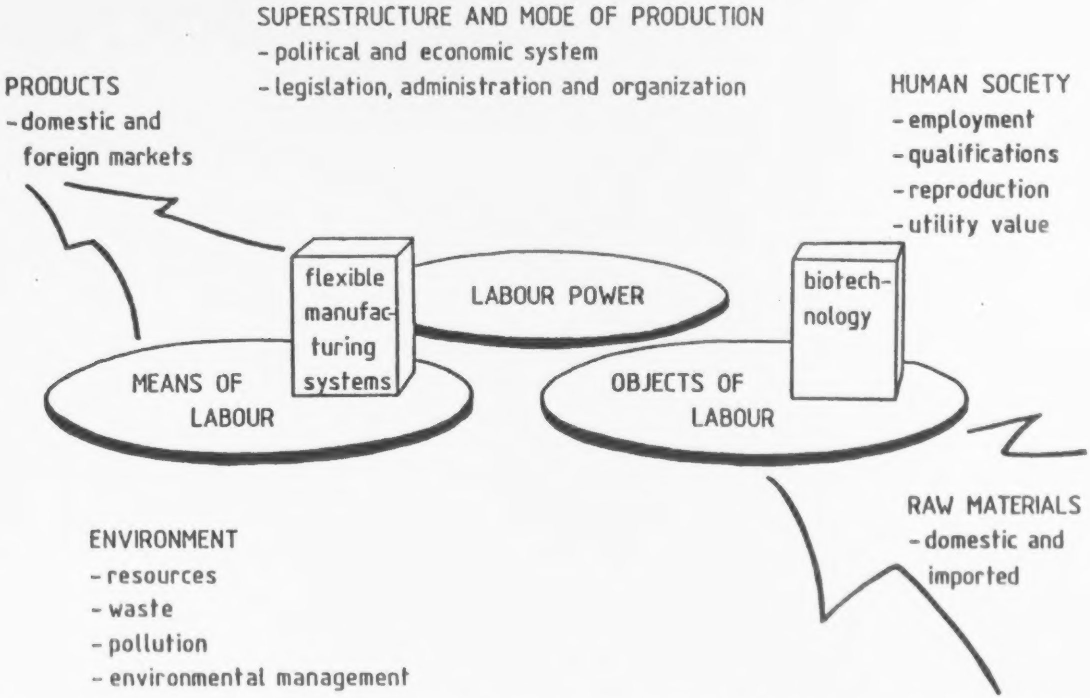
SUPERSTRUCTURE AND MODE OF PRODUCTION
- political and economic system
- legislation, administration and organization
PRODUCTS
- domestic and foreign markets
HUMAN SOCIETY
- employment
- qualifications
- reproduction
- utility value
flexible manufacturing systems
LABOUR POWER
biotechnology
MEANS OF LABOUR
OBJECTS OF LABOUR
RAW MATERIALS
- domestic and imported
ENVIRONMENT
- resources
- waste
- pollution
- environmental management

Figure 1. A theoretical frame for technology understanding. See text for further explanation.

on the production process, but also on the surroundings (i.e. the environment and the human society), and iii. the model can be viewed in a dynamic way, the different parts changing in time and space.

Changes in one part of the model give direct or indirect changes in the other parts - sooner or later. Production can change the environment directly either by pollution or by depleting resources. When pollution reaches high levels, individuals react by forming movements - or the established society reacts with restrictions. In this way the environment indirectly affects the applied production and technology. New objects of labour require new means and new qualifications of the labour power. One form of production can directly prevent another form by destroying the resources - thus forcing one of them to move in space.

Some of the "new technologies" are inserted in the model. The computer-directed flexible manufactoring systems are new means of production, requiring quite new qualifications of the labour power. The biotechnologies should in the present state of affairs be placed as new objects requiring new means of labour. Further elaboration of the biotechnologies will make cell-cultures new means of labour, necessitating the application of new objects.

The purpose of secondary school is to teach the students not how to use technology, but to evaluate technology on the basis of a general knowledge of how the technology is used and how it affects the society and the environment. In addition they should obtain specific knowledge of technological methods and principles in reference to further education and future employments.

For both purposes the model is relevant for systemizing this knowledge, although it is too abstract for most students in theoretical form. Practical work should therefore always be integrated in technology-teaching as a basis for theoretical discussions as exemplified in the next part.

"Traditional" technology.

The following example shows how the theoretical model can be used in practice. My students wanted insight in food-processing technology through a practical example of food-production. A serious accident at a factory in Copenhagen producing vegetable oils and soya-bean cakes was the motivation for working with margarine.

The accident was caused by explosion of benzine. The first questions from the students were: Why is benzine used in the production of vegetable oils? Why are people discussing the fear of chlorine? Why all this talk of mercury?

They decided to work out a flow-diagram for the production process - it was in fact possible just from the newspaper articles (figure 2). The students found it exciting to look into a quite new world, and they decided to make margarine from soya-beans step by step in order to get a better understanding of the processes in the factory.

Besides getting an understanding of food-technology, the students along the way poses a number of questions that are ne-

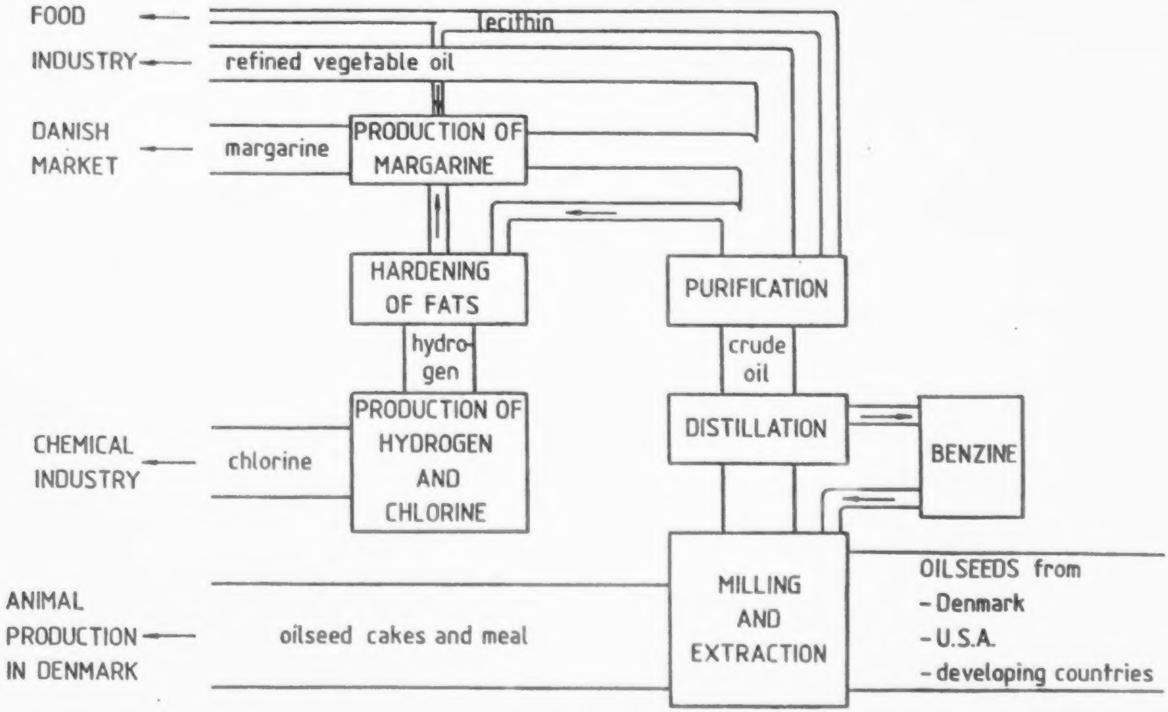
FOOD
INDUSTRY
lecithin
refined vegetable oil
DANISH
MARKET
margarine
PRODUCTION OF MARGARINE
HARDENING OF FATS
PURIFICATION
hydrogen
crude oil
PRODUCTION OF HYDROGEN AND CHLORINE
DISTILLATION
BENZINE
CHEMICAL
INDUSTRY
chlorine
MILLING AND EXTRACTION
OILSEEDS from
- Denmark
- U.S.A.
- developing countries
ANIMAL
PRODUCTION
IN DENMARK
oilseed cakes and meal

Figure 2. Flow diagram for production of vegetable oils and margarine.

cessary for the evaluation of technologies.

The questions can be categorized according to the model (fig. 1) starting on the right side of the figure. The first category of questions concerned the raw materials and their origin. The questions gave rise to discussions of the protein-import from developing countries to a comprehension of the international market for nutrients as well as the historical background for the location of the factory,which lies at the harbour in the center of Copenhagen.

The second category of questions concerned the production itself, the means and processes. These were answered through practical work in the laboratory. The students who had almost no experience in laboratory work learned a lot about the properties of lipids and proteins, about purification, distillation, separation, and centrifugation processes, etc.

They also learned how to handle various equipment, observance of safety rules to avoid hazards (handling strong acids and bases, mercury, chlorine and the distillation of benzine).

This of course gave rise to the third category of questions: the work environment in the factory. In particular the problems of organic solvents affecting the nervous system was discussed.

The fourth category of questions concerning the outer environment came up naturally as hydrogen was produced with a mercury electrode and chlorine as a secondary product. The uneasiness of the local population became evident. Later on in the course this problem was further analyzed in a project concerning mercury in the environment.

Finally the role of the products in the Danish society was discussed, particularly the nutritional value of the produced margarine and the role of food additives in provoking allergic responses. (The students actually produced margarine from oil by adding hardened fats, water, milkpowder, colour, emulsifier, and salt, but the lack of a usable flavour made it extremely distasteful).

Biotechnology.

Biotechnology plays a major role in the new technologies although it has not yet developed to the same extend as computer technology. The term "biotechnology" includes a number of technologies, originating from molecular biology, and usually defined as "the technical use of biological knowledge in production". In this broad definition the bread-making process with the use of yeast, alcoholfermentation, selection of domestic animals etc. are included. In the context of "new technologies" the driving force is comprehension of biological information, and only the "deliberate use of biological informations in production and reproduction" will be considered as "biotechnologies" in the following.

Biological informations are stored in different macro-molecules, but until now attention has been focused on DNA, RNA and proteins - mainly because information of other molecules is not accessible.

The different techniques are developed more or less independently, but only combinations make rapid advances: protein production from microorganisms for specific purposes has long been known, but only when combined with the techniques of splitting, splicing, and cloning DNA from various sources did it become a revolutionary technical improvement.

a. In industrial production.

The use of biotechnology in industrial production is based on the fermentation technique - the alcoholfermentation being an old and well-known example (fermentation is the microbial production of specific products by monoclonal cultivation under optimal conditions. The products are more or less effectively purified from the nutritional medium).
Through a better understanding of mutagenesis and selection the fermentation technique has been improved by making the microorganisms still more effective in producing the desired products. The increased application of enzymes and other fermentation products has also resulted in a rapidly growing market. The introduction of immobilized enzymes has made it increasingly economically to use enzyme-techniques instead of traditional chemical processes.
Furthermore enzymes provides many advantages in terms of energy-use, intermediate and waste-products being biologically convertible, creating less serious hazards etc.
With the introduction of genetic engineering the number of different products made by fermentation techniques has increased considerably. The creation of artificial DNA is only limited by our understanding and imagination. As an example the

development of cheap immunoglobulins could revolutionize purification processes.

b. In agriculture.

Selection of plants and animals with desired characteristics is an ancient technique, but has until recently been a very slow process. The freezing of semen, eggs and embryos offered new prospects. Hormone-induced superovulation and *in vitro* fertilisation increased the speed and possibilities. The success of inserting specific genes in fertilized eggs can induce revolutionary changes in the procedure - thus it is not only characters originated by chance that can be selected, but also characters introduced from other organisms.

In plants the efforts are concentrated on producing species that require lower amounts of fertilizers and pesticides. Transfer of genes between species opens up the possibility of making nitrogen-fixating cereals.

The mentioned techniques brings forth several positive aspects including more economical use of organic production, reduced need of fertilizers and pesticides - resulting in more food to the world population and a cleaner environment. But it may also lead to the depletion of the total genetic information in the world leaving fewer possibilities for future generations. And one should not forget the side-effects of the so called "green revolution" introduced during the sixties in the developing countries.

c. In medical treatment.

Many medical products are made by fermentation, but until lately they have been limited to naturally occurring microbial products, although some chemical modifications are done. Introduction of genetic engineering removes this limit, and in principle all naturally occurring products can be made by microorganisms. It should be stressed though that the question of making species-foreign products is not so much a question of finding the right piece of DNA, but more of finding the right conditions for the production.

Within the last few years the making of "test-tube" babies has become routine work, and the techniques evolved in agricultural research on animals are applicable to humans - with all the moral and ethical implications.

The rapidly growing understanding of human genetics and chromosomes in combination with immunological and enzymological techniques has already given the prenatal diagnostics a push forward, which very soon may leave the woman in the street without any real influence in deciding whether her baby should be born or not.

Chimaers probably are of little economic interest, but they have great scientific importance in studies of human genetics and development. Chimaers of humans and chimpanzees in test-tubes might facilitate the way to better understanding of communication between cells and genes.

Gene therapy has been practised on two occasions, but was strongly critizised by experts. Not because of the ethical implications - but because the techniques have not yet been sufficiently developed.

d. In the future.

Many of the biotechnological inventions are still on the laboratory scale, but the investments in research are so huge that the question of practical use is largely a question of time. A short glimpse on the stock market gives the assurance that biotechnology is doomed to success due alone to the size of investments. An example are the investments in research of the pharmaceutical concern NOVO with dimensions comparable to the entire budget of the Faculty of Sciences at the University of Copenhagen.

A short official note from the Common Market requests that the member-countries should make efforts to strenghten the biotechnological research in order not to lose ground to countries as the U.S.A. and Japan. The note predicts the comming of a "bio-society" succeeding the "information-society". At least two new areas of great interest are in the making: energy-production and the "bio-computer".

Conversion of solar energy to electrical power by plants and the splitting of water to hydrogen and oxygen are relatively well-known processes. The technical use of that knowledge could give several advantages: reduced problems with pollution and resources and a lower demand of materials for installations (utilisation of mono- and bilayer lipids and monomolecular cabels).

The code of DNA is also well-known, although more knowledge tends to complicate matters. The information of proteins is intricate and rather poorly understood - possibilities seem to be inumerable. The "protein-chip" might not only be advantageous in size and energyspending, but in function as well, making even the smallest chip of the eighties look coarse and primitive.

To the layman both examples are rather speculative, and questions of reproduction-techniques are much more urgent. How far do we want the development of prenatal diagnosis to go? What are the juridicial and ethical implications of the "test-tube" techniques? And so on.

The Danish Home Secretary has made an effort to describe these problems - unfortunately in a very insufficient report.

In the society there is a tendency to a dual development: On one hand a continous introduction of new techniques in hospitals, on the other hand a movement for more humane treatment. The public discussion of what we really want has barely begun.

e. In the secondary school.

Most students of the secondary school are very interested in knowing more about biotechnology. They are confronted with its aspects in news-papers, books, films etc., but often they have a very undifferentiated view - either the very optimistic view of the technology as a solution to any problem, or the horror-view of books like "Brave new World".

This is due partly to the lack of biochemical and genetic knowledge and partly to a very limited understanding of the technological development.

Biology teachers of the secondary school in Denmark have gathered some experiences during the last years. Biotechnology concerns production as well as reproduction, each providing possibilities and approaches which should be part of the education. Not only because the two topics are interlinked, but also because girls usually a priori are more interested in the reproductive aspects, while boys are interested in the productive aspects. The motivation for "the other aspect" emerges through a better understanding of the problems.

Understanding biotechnology is not just a question of learning the underlying techniques and acquiring scientific knowledge. It is also necessary to understand the role of the technology in the society, the moral and ethical questions and which consequences the application of this technology might have for the environment, the individual, the country and the world community. A high level of understanding is reached only through this very holistic point of view.

Furthermore an experimental approach is suitable to ensure that discussions do not become too theoretical and hypothetical which tends to draw away discussions from the real problems to an irresponsible fantasy-world.

f. A practical example.

The following project is chosen to show how it is possible to work with practical biotechnological problems in the secondary school. The class had a great majority of boys, and the approach was genetic engineering in production. The purpose of the project was to enable the students to distinguish facts from fiction in informations from radio, television, news-papers and popular magazines.

The students were asked to imagine themselves as a newly established research group on a factory producing enzymes for industrial use. They had a bacterial strain that - by chance - was found to produce a certain enzyme in large amounts. Having this strain meant that the enzyme could become commercially feasible to the factory.

The research group (alias the class) was now asked to answer the following questions:

- could commercial production of the enzyme be established?
- which kind of purification processes would be suitable?
- could the genetic information be characterized and integrated in a more convenient strain?
- could the factory take out a patent for the genetic information and the production?

(It must be noted that the strain was already well characterized by professionel bacteriologists and recommended for this project).

A convenient assay for the enzyme and procedures for gel-making, proteinseparation, and DNA-extraction were found in the litterature before starting the practical work.

Preliminary experiments were performed to train the students in the necessary biological methods (cultivating bacteria, practicing sterile technique, recognizing the phenotype of the strain, determining enzyme activity).

The next step was to cultivate the strain in larger quantities for enzyme preparations. The students were organized in five teams, each workning with different procedures of extraction. The methods were compared and evaluated in terms of yield and purity. The best method was used to prepare enzymes for further purification, which was done by precipitation. The product was now accepted by the class as sufficiently good for industrial use. The first two questions had been answered.

The genetic information of the strain could not be transferred to other strains in vivo, but DNA-preparations could be made and analyzed by gel-electrophoresis. A characteristic band of small-molecular DNA showed up on the gels: a plasmid. A new strain was then prepared for in vitro transformation and mixed with the DNA-preparations.

The result was overwhelming - hundreds of colonies with the expected phenotype. The genetic information (located on the plasmid) was established in the new strain, and the students were able to show that the plasmid had been assimilated by bacteria now having a high enzyme production. Thus the genetic information for high enzyme production had to be located on the plasmid, which answered the third question.

The fourth and last question was only discussed theoretically due to lack of time.

Besides learning a lot about general biological phenomenas and methods (in genetics, biochemistry and biotechnology), the students had to learn - and practice - laboratory safety rules: personal safety, responsibility to other persons entering the laboratory, and wastehandling. Through the practical work they also learned to make critical evaluations of the information they got from different sources - and to argue intelligently about possibilities and problems of biotechnology in industrial production.

The reproductive aspects were not integrated in this project, but the class had previously studied sexology and human physiology and thus had a basis for spontaneous discussions of the relevant reproductive aspects.

Conclusions.

The two cases from technology-teaching in biology are both taken from low level biology-teaching - each case taking up one third of available biology lessons (both cases lasting about 12 weeks). In this view they are rather large projects, but with aspects that I find essential to technology-education at the secondary school level.

Both cases included large amounts of practical work. The questions posed by the students were consequences of this practical work and therefore realistic and relevant to the actual problems in the use of the discussed technologies.

The cases also fulfil the theoretical considerations presented in fig. 1 - to view technology as part of the activities in society - not only affecting production, but also the workers, the population, the environment, and the economy of the society.

Knowledge of a particular production or a factory can also be achieved by visiting an establishment. But it is my experience from short visits that these often tend to be too superficial for secondary school students, and that longer visits - 5 to 10 days - are only accomplished with many obstacles. Only a few factories are interested enough to take the trouble, and the school system of Denmark is not adjusted to this kind of education.

In many cases, I find it more convenient to make the actual production in the school laboratory on a small scale. It is easier for the students to survey the different parts of the production and the technology used, and it is possible to take a break for a while in order to solve theoretical problems at the appropriate moment, not several days later, when some of the impressions have vanished.

A combination of a "home-production" and a visit provides good knowledge and understanding of applied technology. Understanding the role of technology in the development of the society requires knowledge from other subjects than the sciences (economy, history and geography), whereas evaluating technology furthermore requires ecological, sociological, political and ethical considerations.

Limitations in the school structures impede a total integration of different subjects. In practise it is therefore necessary to work within a less idealistic frame as demonstrated in the cases above.

These considerations concern both "traditional" technology and the "new technologies". But whereas the consequences of traditional technologies are well described, very little is known about how "new technologies" will influence employment, pollution and the structure of world economics.

At the present time, biotechnology is only developed in the richest countries of the world, but could it possibly be a technology for the developing countries in order to speed up economic growth? Or will it to the contrary deepen the cleft between rich and poor countries in the view of the existing world economic order? Can biotechnology be used to solve the problems of malnutrition, or will biotechnology-production replace the most polluting productions in the rich countries, while these are transferred to developing countries causing environmental problems there?

These unanswered questions might seem speculative at this moment, but it is the students of today that are going to make the decisions.

Postscript.

While writing this article, the first application for permission to start a commercial production of a human protein (insulin) from bacteria was submitted in Denmark. The bacteria are a result of genetic engineering. It is unknown when the permission will be given, because the county council did not find itself competent to treat the application!

FOCUS ON EVERY-DAY CHEMICAL EXPERIENCE IN THE SCHOOL

Motivation of narcissists and concrete thinkers.

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Compared to the situation in other developed countries the general chemical education in the Danish school is not very impressing. With the present school intact, almost 80 % of the adult population of 2 000 a.c. will have almost no idea of chemistry in a world where chemical phenomena and their proper understanding become increasingly important.

Three different aims and some boundary conditions

The national curriculum for chemistry in the upper secondary school (the gymnasium) describes in general and in chemical terms, what should be taught in chemistry and stresses the importance of experiments and a quantitative treatment.
The formulations give the impression that the aim is mainly to educate in chemistry, whereas the aim to educate through chemistry is not pointed out, and the aim to educate about chemistry is only rather weakly expressed.
Furthermore, the students' yield (- their knowledge at the end of the course -) is by no means formulated in, for example, Bloomian cognitive or affective taxonomy.
It is, therefore, nessecary to consider in detail what and how (and at which level) should be taught. This leaves a certain amount of freedom to the individual teacher, although the non-official syllabus lies in tradition and in the textbooks available.

Factors governing the motivation

Some changes in the school system seem possible including more science teaching for a greater fraction of the future youth. Even in the present science line of the gymnasium it is nessecary to consider how to motivate the students for chemistry; so, in the the near future the question of motivation will become one of the most important points for chemical didactics. At least three fairly new factors should influence these didactic considerations:

1. The generally negative attitude towards chemistry, chemists, chemical industry and "synthetic" products such as plastics, fertilizers, medicines, solvents in paints, detergents, pesticides, food additives and so forth, was created during the late sixties and early seventies. It still persists, partly due to the mass media not being sufficiently aware of the differences between chemistry as subject of knowledge and the side effects of its technological uses. This sometimes hostile attitude is transferred in some "version" to the students by their parents, the mass media and advertisements.
2. Narcissistic trends in society
   Our complicated world is not easy to grasp, politically economically, socially and culturally. Rather profound changes did occur during the whole life of the present youth, so a tendency towards a narcissistic behavior is not difficult to understand. This inhibits the 16 years old students' curiosity about how nature works. I wonder how many students just feel chemistry or chemical fact "fun".
3. The greater fraction of concrete operational thinkers
   There is a growing understanding that the exact subjects in school, such as physics and chemistry, demand formal thinking (in the Piaget sense) and that the typical 16 years old student is primarily at a concrete operational level and is only in the process towards a more formal operational stage. The increased number of students to be taught science - including chemistry - will stress

the importance of this factor.

I guess that not many science teachers would disagree if chemistry presented itself as funny, interesting, relevant and as a powerful tool for the critical formulation and solution of problems in every-day life.
How, then should we meet the students at their level of knowledge and in their world of thinking and motivate them for chemistry?

One approach is to look at chemistry being around us (cf. also the project described in the contribution by Poul Erik Hansen)

In the household we meet pure compounds, such as sodium chloride, sucrose, monosodium glutaminate, ammonia, baking soda, potassium nitrate, acetic acid, butane, calcium carbonate, copper, carbondioxide etc. and we regularly use chemical products such as baking powder, oils and fats, food preservation and colouring agents, pain killers, plastic and metallic utensils, soaps, detergents and other cleaning agents, glues, paints, gas, petrol, fuel oils, fertilizers, pesticides, batteries etc., all of which has desired (and non-desired) properties depending heavily on their chemistry.
The treatment of some of these compounds or products is suitable as examples in a deductively edited textbook, while others may be used for inductive approaches to cover important areas of chemistry. The theme "Gas, petrol and fuel oil" is, for example, suitable to introduce organic chemistry, including hydrocarbons and basic nomenclature, whereas the treatment of analgetics can cover the introduction to the functional groups and their chemistry.
We are actually preparing some material about "Over-the-counter Painkillers" along these lines including: The history of painkilling. Drugs and the isolation and identifi-

cation of the active component. Molecular structure of salicylic acids and derivatives, and some of their chemical properties. Membranes, and the administration, uptake, and metabolism of acetylsalicylic acid (ASA). The mechanism of drug action and simple models for the action of ASA. Receptors and the mechanism of pain and its natural relief. Industrial synthesis of ASA. Procedure for the preparation and control by society of drugs. The use of medicines in Denmark.

From the syllabus point of view, the material includes aromatic systems, important functional groups, principles of identification, synthetic procedures, kinetics of hydrolysis, acid-base and phase equilibria, coordination chemistry and formation constants, chemical "affinity" and stability etc.

Although the consumption of lessons could easily amount to about 20, neither the "education in" or "through" aspects are disregarded, whereas the "education about" facet is more pronounced than is usually seen in Danish textbooks. It might seem to be a rather moderate aim, but still a tempting suggestion, that the first important point is that and not what the students learn.

This project is done in collaboration with Poul Erik Hansen.

SEARCHING FOR PATTERNS OF KNOWLEDGE IN SCIENCE EDUCATION

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SUMMARY

The exponential growth of scientific and technical information demands new approaches to its processing, mainly supported by the computer. In addition to numerous bibliographic data bases, factographic data bases are being developed, oriented towards selected fields of science and/or technology. Structuring information into systems enabling pattern recognition represents the next level. Structured data bases support the building of expert systems for solving selected problems. Such systems also include simulations and hypothetical predictions, as well as their testing. A new methodology is being developed: searching of patterns of knowledge, "knowledge engineering". It opens up insights into relationships between large sets of data and enables the recognition of backbones of knowledge.
Our research supports the construction of bibliographic and factographic data bases, with structuring of data into systems, needed for solving educational and research problems, as well as for the transfer of knowledge to industry.

Faces of science

There are two main reasons for good science education and further life-long education:

- in the industrial, end even more in the post-industrial era of man's development, every career, even every day-to-day activity, involves science and technology, supported increasingly by mathematics and informatics;
- growing democratization processes involve an increasing part of the population in decision making.

Science, this achievement of research, has many faces, depending on the individual approaching it.

For a researcher, science means the results of objective observation, supported by powerful methods and techniques, with an analytical treatment of the data collected and a search for interrelationships between them, followed by a synthesis of these data enabling explanation of processes and recognition of patterns, which thus lay the foundation for hypothetical predictions to be checked by further research.

For the engineer and technician, scientific information is the starting point for developmental efforts, giving a fundamental orientation and stimulating creativity in searching for the useful applications of scientific achievements.

To a manager, science offers a basis for predicting several possible solutions of real problems which help him to understand the nature and implications of different possibilities needed in his efforts to optimize processes.

The quality of science and thus also of science education increases from the level of objective observation supported by efficient techniques, via organizing data and expressing interrelationships with diagrams, leading to the formulation of the interrelationships recognized in the form of abstract mathematical equations. These express relationships in the shortest, most accurate and logical way.

Entering the information era

The little silicon chip with its increasing capacity belongs to the discoveries which are bringing fundamental changes to education also. In 1971 a thousand bits of information could be housed on a single chip, in 1978 sixty four thousand, while by 1990 a million-bit chip is expected. Fibre optics and satellite communication promise great contributions to the world system of communication.

These techniques are urgently needed since scientific and technical information is growing in most disciplines exponentially. In chemistry(1), for example, over four hundred thousand papers and a hundred thousand patents are published annually. Over six million compounds are registered in the Chemical Abstracts Service Registry and about three hundred thousand new compounds are added each year, i.e. about one thousand a day. The only solution is the construction and use of computer-supported data bases.

The construction of the first data bases supported by the computer started in the sixties. They were at first designed for local use and constructed in national languages.

In the seventies it became clear that for computerized scientific and technical information too a critical mass is needed to enable quality and efficiency in use: a critical quantity of data, finance, equipment and specialized staff.

The results of this awareness were efforts to combine small data bases into larger ones, which implied standardization of the input and modes of retrieval. The next step was logical: an interlinking of computerized data bases into networks and large information systems of an international character. In the eighties we can speak about the development of an information industry. We are entering the information era.

Over two thousand computerized data bases of an international character exist today. Chemical Abstracts Search (CASEARCH) data base houses information on over six million compounds and over five million papers. AGRICOLA offers about two million data on agricultural publications, COMPENDEX one million on engineering. INSPEC covers over two million electrical engineering publications, MEDLARS has about five million data on publications in medicine and veterine. The multidisciplinary BIOSIS houses four million data on biology, medicine and veterine, TOXLINE two million on pharmacy and pharmacology. The strongest, International Patent Documentation INPADOC, offers information on over ten million patents from 49 countries plus two international patent organizations. A number of these and other data bases are parts of large systems such as DIALOG, DARC etc.

From fragments to systems

Computerized technology is opening up rapid access to scientific data. Yet not only the layman, but often also the researcher, does not know what to do with large sets of data.Systems-thinking is missing, i.e. an organized way of linking bits of information into networks, trees, modular systems, showing the interrelationships between large sets of data.

How much systems-thinking is needed can best be illustrated by how poorly data bases are used. Even in the most developed circumstances, data banks report that only 5 - 10 per cent of the data stored has ever been asked for. This is the reason why some call data bases "scientific cemeteries". Another proof is the fact that the market is flooded with sophisticated hardware with relatively scarce, often also poor, software.

The development of good software does not require only ability and patience, but also organized thinking, typical of good researchers, yet obviously a rare gift of nature. We have to learn how to structure data into systems, how to organize data into knowledge. Students should not be taught the content. They should be encouraged to define real problems, to collect and analyze data, to search for common parts and variables, to define the hierarchical order of variables, to structure the hypothetical system and to try to validate it - in short: to use the method of structuring data and pattern recognition.

Towards expert systems

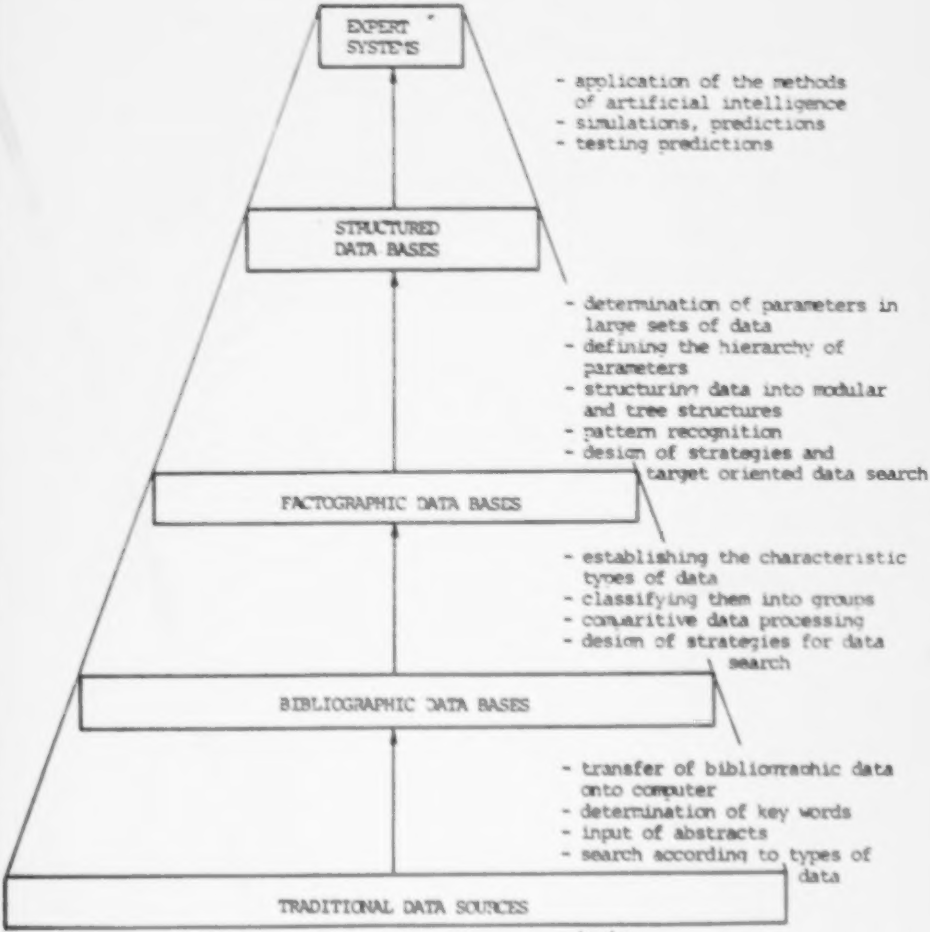
Expert systems are considered to be the top of computerized scientific and technological information. They are complete programmes which support the linking of large groups of facts leading to expert problem solving.

Examples in this field are the expert systems for diagnostic purposes in medicine, design of computer system configurations, search for minerals, natural gas and oil, design of chemical syntheses, detection of failures in electronic devices, prediction in market movements, etc.

The main characteristic feature of these systems is that they take into account a number of parameters and larger amounts of data than possible by human brains. Although they cannot compete with the logic of a researcher they are significantly better in comparative analysis of large sets of data and in combination of parameters, in scope and in particular in speed.

It could be said that a kind of knowledge engineering is being developed, which is still in its initial stages, but will undoubtedly greatly influence the processes in research and education, as well as solving problems in production and decision making.

Secondary, but no less important, consequence of the process of development of expert systems is the fact that knowledge engineering catalyses the efforts in collecting, coding, exchange and application of human knowledge on a world wide scale. This means that knowledge engineering leads to the development of larger systems of knowledge, and along with this also supports the development of understanding and efficient target-oriented acquisition of knowledge. Instead of acquiring tiny pieces of information, masses of information will be introduced in science education in future. They will be organised into systems,which will on one hand show the already defined relations and hypothetically forecast new relationships on the other. Instead of a disordered search for the new, it will be possible, by the use of these systems, to design research hypotheses and with a target oriented research to approach more quickly to the solutions. Intuition and chance will of course still have their role in research. But it is also true that expert systems will aid in finding knowledge much more quickly than it was possible up till now, in particular knowledge which has already been discovered but which is hidden. Strategic and technological secrets will become less inaccessible. This will also give a totally new impetus to education.


EXPERT SYSTEMS
STRUCTURED DATA BASES
FACTOGRAPHIC DATA BASES
BIBLIOGRAPHIC DATA BASES
TRADITIONAL DATA SOURCES

- application of the methods of artificial intelligence
- simulations, predictions
- testing predictions

- determination of parameters in large sets of data
- defining the hierarchy of parameters
- structuring data into modular and tree structures
- pattern recognition
- design of strategies and target oriented data search

- establishing the characteristic types of data
- classifying them into groups
- comparitive data processing
- design of strategies for data search

- transfer of bibliographic data onto computer
- determination of key words
- input of abstracts
- search according to types of data

- books
- journals
- special series
- reports
- patents
- grey literature etc.

From data sources to expert systems

The higher we go up this diagram, the narrower the field, since expert systems are as a rule designed for solving a specific type of problem, whereas structured data bases can be built on less narrow areas of a field and are only afterwards interlinked to larger systems. Factographic data bases also have their limitations, above all in the possibilities for input of and search for data. Bibliographic data bases, however, cover usually broad areas. The traditional data sources - journals, books, special series, patents, grey literature - constitute the broadest basis of the whole system.

The following phases are characteristic of expert system design:

Phase	Characteristics
1. Definition of a problem	recognition of characteristics of the problem
2. Conceptualization	search for laws and rules or at least for the relationships in knowledge necessary for the solution of a problem
3. Formalization	structuring data into systems
4. Implementation	formulation of rules for the knowledge concerned
5. Testing	checking of rules on problems captured in the expert system

Development of methods of structuring data into systems

The main reasons for lagging behind in use and design of data bases, as well as in the development of expert systems, lie in education. Traditional schooling is too often oriented towards memorizing data (lower level), or to development of reasoning based on a relatively small amount of data (higher level). Deductions of rules and laws based on large sets of data are still unknown in our education. Without such an approach we of course do not educate for the use and design of computerized data bases. Therefore no wonder that what "little Johnny has not learnt, John does not know and also does not do".

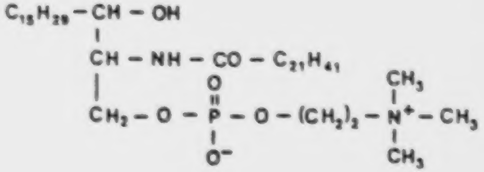
Let me give an example for structuring data into systems at secondary level: lipids. Traditional study of lipids at secondary level includes the description of fats and waxes, phospholipids and glycolipids. In dealing with this subject matter, emphasis is placed mainly on their component parts - on alcohols and acids in the former, whereas the more complicated components of the latter are only briefly mnetioned, if at all. Due to the complexity of these compounds students learn only simple formulae, and the more complicated are usually not considered. Consequently it is very difficult to deduce rules on the basis of such a limited amount of data, and knowledge remains mainly on the lowest level - memorizing.

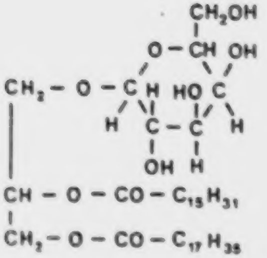
In structuring chemical data:

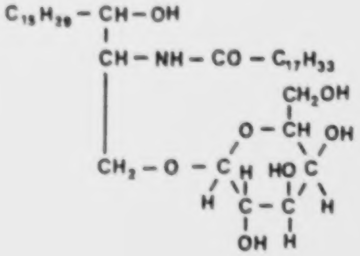
- students use textbooks and find the formulae for different lipids: fats and waxes, phospholipids, glycolipids. They construct a file with the formulae of lipids and eventually other data on each compound;
- this is followed by the search for common part(s) in the formulae of these lipids. They will find glycerol, monohydroxy-alcohols and sphingosine, as well as a number of carbocyclic acids bound in the lipids; they will also find phosphoric acid; amino-alcohols and carbohydrates;
- this could be followed by a discussion of what the criterion of higher hierarchical order is, e.g. alcohol or acid? Students should try to build a tree giving first the higher order to alcohol, and next giving it to the acid part. What are the differences between the two systems?
- they can try to use the data available to construct an overview, e.g. Table 1

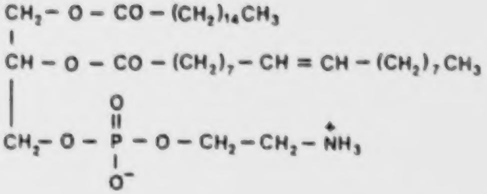
It is not the system produced, but the effort of structuring data into systems which really counts. The student is put into a situation in which he does not only learn from one source, but searches for new data in different sources. He does not only memorize chemical data, he is using them to search for interrelationships. In this way he develops higher cognitive levels, i.e. an analytical mind, meaning the ability to synthesise data, to recognize the interrelationships and to evaluate both - data and systems.

An example of structuring at secondary level: LIPIDS

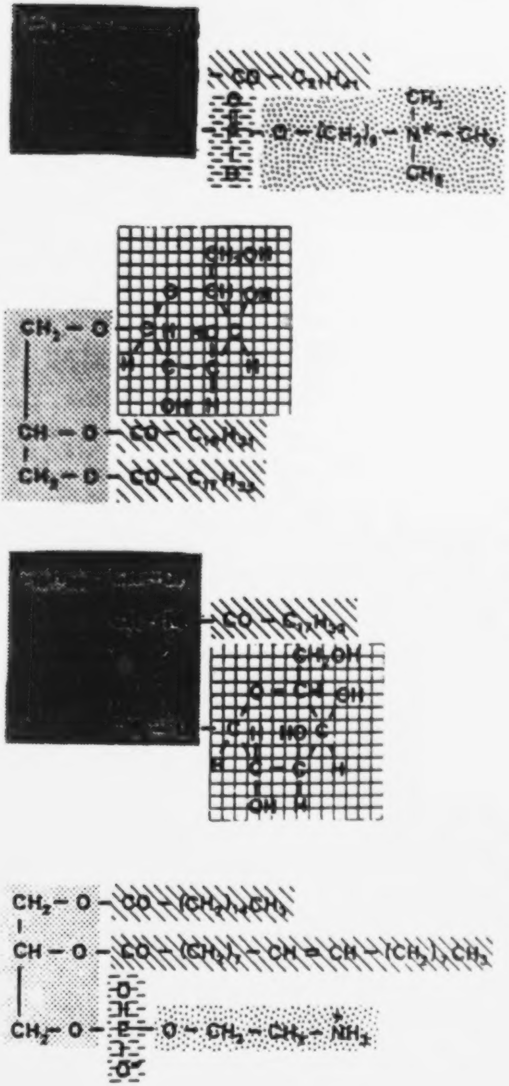




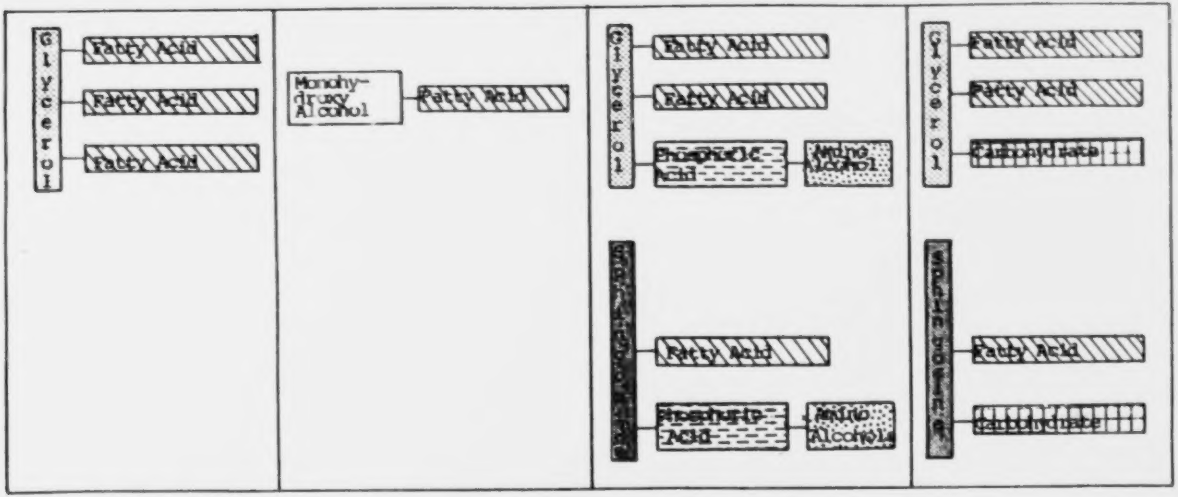




Examples of formulae of lipids - learning by heart would give only short term success.


CO — C21H41
CH3
O — (CH2)2 — N+ — CH3
CH3
CH2OH
OH
CH2 — O
H
HO
OH
CH — O — CO — C15H31
CH2 — O — CO — C17H33
CO — C17H35
CH2OH
CH2 — O — CO — (CH2)14CH3
CH — O — CO — (CH2)7 — CH = CH — (CH2)7CH3
O
CH2 — O — P — O — CH2 — CH2 — NH3+
O−

Recognition of constituents in the formulae of lipids - students observe and recognize parameters and establish their hierarchy.


Glycerol
Fatty Acid
Fatty Acid
Fatty Acid
Monohydroxy Alcohol
Fatty Acid
Glycerol
Fatty Acid
Fatty Acid
Phosphoric Acid
Amino Alcohol
Sphingosine
Fatty Acid
Phosphoric Acid
Amino Alcohol
Glycerol
Fatty Acid
Fatty Acid
Carbohydrate
Sphingosine
Fatty Acid
Carbohydrate

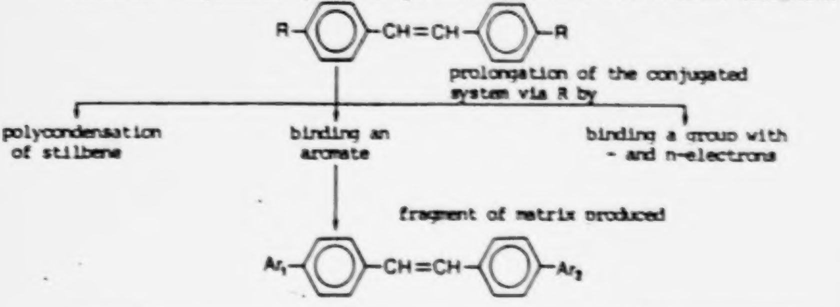
The modular system at secondary level showing interrelationships between individual parameters

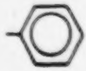
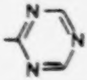
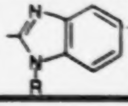
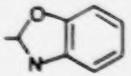
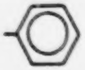
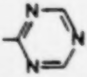
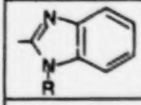
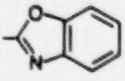
A number of other examples for secondary level could be given, e.g. attempts to build a system of acids and bases, hydrocarbons, oxidations and reductions, types of organic reactions etc. Thus a system could be constructed around the structural parts of a certain group of compounds, around types of reactions, different properties, spectral data, isolation procedures etc. The basic condition - a sufficient amount of data - has, however, always to be fulfilled.

An example at the university level is illustrated by efforts to search for a system of optical brighteners. In this case, the student had first to study phenomena like the relationship between colour, absorption and emission with fluorescence as the special case. This was followed by the collection of data on optical brighteners, using traditional sources of information, as well as computerized chemical and patent data bases. By analysis of the structure of optical brighteners it was found that stilbene derivatives are present in sufficient number to fulfill the condition of a critical amount of data for [illegible] the use of structuring data and the pattern recognition method. The structures of these compounds were then analysed in detail, common parts and variables were recognised, and their hierarchical order determined. The following fragment (table 2) of the system produced offers an illustration.

The work on the system of optical brighteners is being continued by taking fluorescence as the crucial criterion with the intention of searching for a pattern in these compounds of dependence of fluorescence on their structure. Thus, the teaching and learning aspects are combined with research, directed towards the understanding of fluorescence in relation to chemical structure, and including an industrial interest in the synthesis of optical brighteners - stilbene derivatives.

Table 2: System of optical brighteners on the basis of stilbene (fragment)


R
CH=CH
R
prolongation of the conjugated system via R by
polycondensation of stilbene
binding an aromate
binding a group with - and n-electrons
fragment of matrix produced
Ar1
CH=CH
Ar2

Ar_1 \ Ar_2				
	o	•	o	•
	•	o !		
	o	o	•	o
	•	o	o	•

- • found in chemical and/or patent literature
- o prediction
- o! found after prediction

University-industry cooperation

The method of structuring data into systems and pattern recognition is essential in the developmental efforts of industry. There is a flood of patent and scientific information, among which there are also data which can be misguiding and may lead one in a wrong direction. In recent years the publication of strategic, both technological and economic data is increasingly limited. Therefore methods enabling hypothetical predictions are becoming more and more necessary.

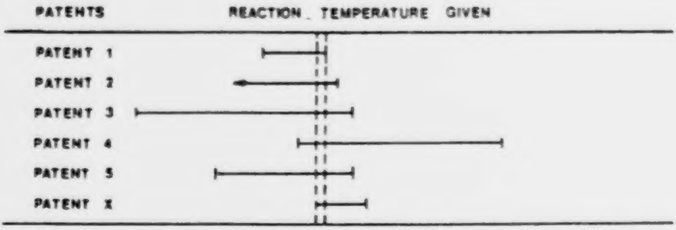
An example in university-industry cooperation is the search for the backbone of the technological process in microencapsulation of a new technology for which in recent years alone more than two thousand patents have been issued. It is of course impossible to deduce the essence of the whole procedure from single patents or small groups of them, since patents deal only with parts of the process, and even here the key information is hidden to the greatest possible extent.

In the search for patterns we started with the largest number of patents which were accessible. This was followed by an analysis of subsets of data from about a hundred patents. Each procedure was structured into a hypothetical "backbone" of the successive technological operations.

In the direct vertical line there are four phases, for which it was first supposed on the basis of data analysis to be unavoidable parts of the backbone of the process. Which are the other parts of the "backbone" ?

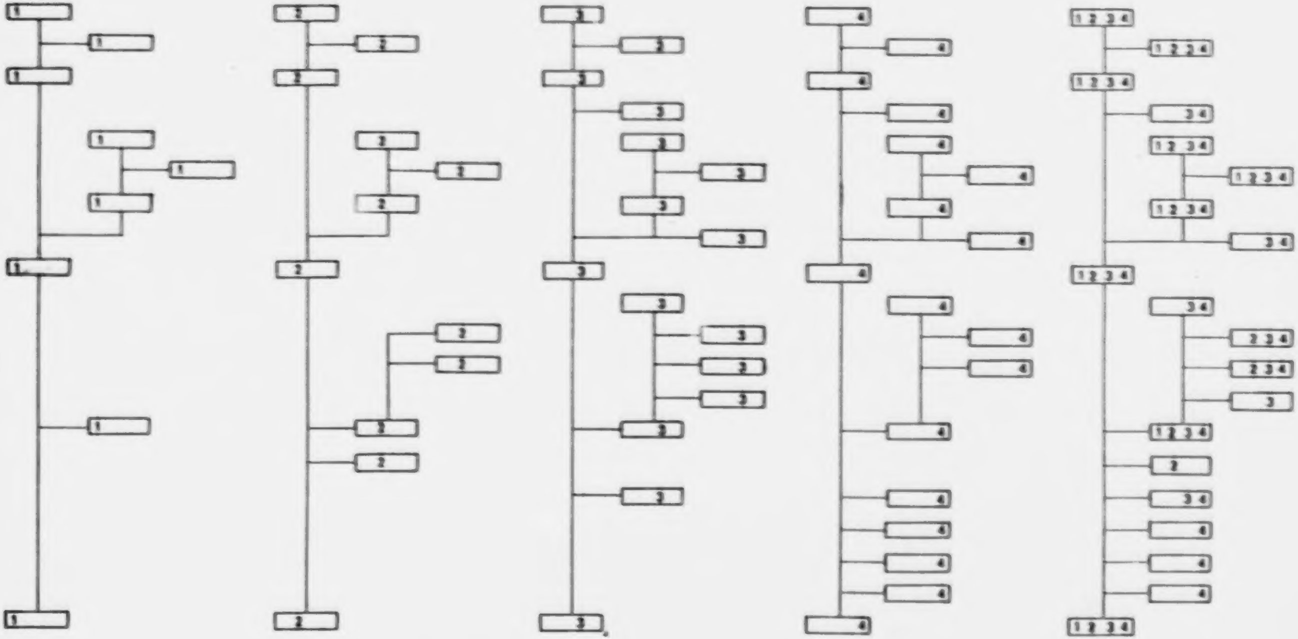
By superimposing those four diagrams, the phases which occur several times can be recognized. The greater the fit of processes for an individual phase, and the higher the number of patents studied, the more probable the "hypothetical backbone" of the process which is deduced from the parts of the diagram obtained by superimposing the different patent structures. (See p.15)

The same applies also to defining the probability of a value of an individual parameter within one phase, e.g. temperature.



The vertical dotted lines show the temperature interval where all the procedures meet, i.e. the most probable value.

Superimposing of patents: each square denotes one technological operation



Patent 1 **Patent 2** **Patent 3** **Patent 4** **Patents 1-4 superimposed**

Backbone of the method

In general, the following stages can be defined in the method of structuring data into systems and recognition of relationships and patterns:

1. Definition of the problem and subproblems

   e.g. : How to improve the existing technology?

   The subproblems are:
   Which variants for this technology exist?
   What are the alternative technologies?
   Which producers use those technologies?
   What are patents, offers of licences like?
   Etc.

   In short, we should formulate such questions as would lead us to the sources of suitable data.

2. Collecting data

   Use of special publications, journals, patents, industrial offers, etc.;
   profile design, search through scientific patent and market data bases;

3. Analysis of the collected documents
   Search for the structure of each process, definition of parameters;

4. Comparative study of each parameter and its relations;

5. Search for common characteristics, building up hypothetical patterns;

6. Stating hypothetical predictions on the basis of patterns and their check by experimental work.

Design of computerized data bases as a component of education

The method of structuring mentioned above always requires a large amount of data if it is to be efficient in research or in development. This means that along with each approach to the use of such methods, we actually also become involved with the design of specialised data bases.

Therefore it is necessary to start constructing and using computerized data bases in school, e.g. for data on energy, metals, non-metals, reaction processes, rise and fall of prices, etc. Only on condition that both, the teacher and the student, are exposed to such data bases which offer the required data and comparisons between them within a few seconds, can we expect them to turn to higher levels of knowledge, i.e. to the understanding of data and their interrelatedness, as well as the use, analysis, combination and evaluation of data.

On the level of higher education, the building of data bases is an imperative. These are of course specialized data bases for problem-oriented tasks, for which the bibliographic data base is only the first step to a factographic and further to a structured data base, leading finally to the development and incorporation of at least some elements of expert systems.

Education for the use of data bases is therefore not only learning how to find information quickly on what has already been discovered. Such an approach would soon convert the initial enthusiasm to lack of interest, due to the disillusionment caused by badly designed searching, which leads to a costly and excessive number of hits with little value.

Data bases in education become an indispensable part only if they are not just a collection of data, but the first step towards higher levels, presented in the diagram on page 6.

This however requires a different way of thinking and therefore also a different kind of education. We have to establish a transition:

- from dealing with separate data to dealing with sets of data,
- from putting together small numbers of variables to building systems with large numbers of variables,

as well as

- from insufficiently organized searching for new knowledge to a long term, carefully planned collection, arrangement and combination of data into systems which are directed towards well defined disciplines or developmental problems.

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A VISIT TO A FACTORY AS A PART OF PHYSICS AND CHEMISTRY EDUCATION AND ITS LEARNING OUTCOMES IN THE SENIOR SECONDARY SCHOOL IN FINLAND

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Chief Inspector
National Board of General Education
Finland

1. Background

In 1979 The Finnish Government stated that the theme "Education to the world of work and technology" should be taught as a part of physics and social studies and not as a separate subject in the senior secondary school.

Following this decision a new goal for the physics education was given: "to make pupils acquainted with the technology on which production is based and with working life and production."

2. Searching for a method

During past three years a model for industry visits for physics and chemistry education has been created in close co-operation between school and industry. The visits have been designed around the idea of an active pupil involvement concerning the physics and chemistry applied in the factory. The model for the visits was created and tested during four in-service courses for physics and chemistry teachers in Heinola, a small town with a lot of industry round it. The activities and the results from the four courses are described in table 1:

Table 1: The formation of the model of the visit to a factory during the four courses held in the Heinola Course Center

The purpose and the activities of the course	results
Course 1: Preliminary studies	
11 factories were visited each by a group of 3-4 teachers who tried to find out if the factory made use of such kind of physics or chemistry that is relevant for the senior secondary teaching. The findings were listed.	Every factory made use of a lot of physics and chemistry. The conclusion was drawn that every kind of factory applies a lot of physics and chemistry, relevant for a secondary school pupil.
Course 2: Model forming	
The same 11 factories were visited by the groups of 4-5 teachers, who planned together with the staff of the factory a program for a pupil's visit. Especially, pupils' own activity was to be encouraged in the programs (measurements, definitions, small studies etc.)	In 10 factories it was possible to let the pupils work themselves. The structure of the programs and the share of the time varied from factory to factory All the visits could be presented by one scheme. (Fig) the "Heinola model".
Course 3: Testing the model	
- Three of the factories were visited by a group of 22 teachers each. The teachers played the pupils' role and tested the program made by the course 2. - Pupils from the local senior secondary school visited one of the factories following the lines of the programme made by the course 2. They reported their visit to the audience that was formed by the participants of the course 3, local and national school authorities, representatives of the teachers' association and local industry.	- Despite of some minor difficulties all of the three programmes worked well. - The pupils' report was a great success. After reporting, it became evident that the model in question is practicable. - No simulation can replace the pupils' own presentation. This has been kept in mind when "selling" the model further.
Course 4: Evaluation	
The participants of the course were told by teachers, representatives of the teachers' association, school administration and industry the experience that each of them had gained about the model in practice. Some pupils from the local school reported the visit they had made during the previous course. The teachers, then, visited the same factory and they got aquainted with the working sites of the pupils. All of this was followed by a discussion.	It was clearly seen that a careful planning not only of the theoretical side of the visit but also of the practical side is a necessity. Most of the audience were encouraged to start or to continue the practice of organizing visits to industry.

3. The model of the visit

During the visit pupils make themselves some measurements, experiments or some other kind of studies that are closely related to the factory and the subject area studied in the school. Reporting the visit is an important part of the project. Careful planning is a prerequisite of the visit.

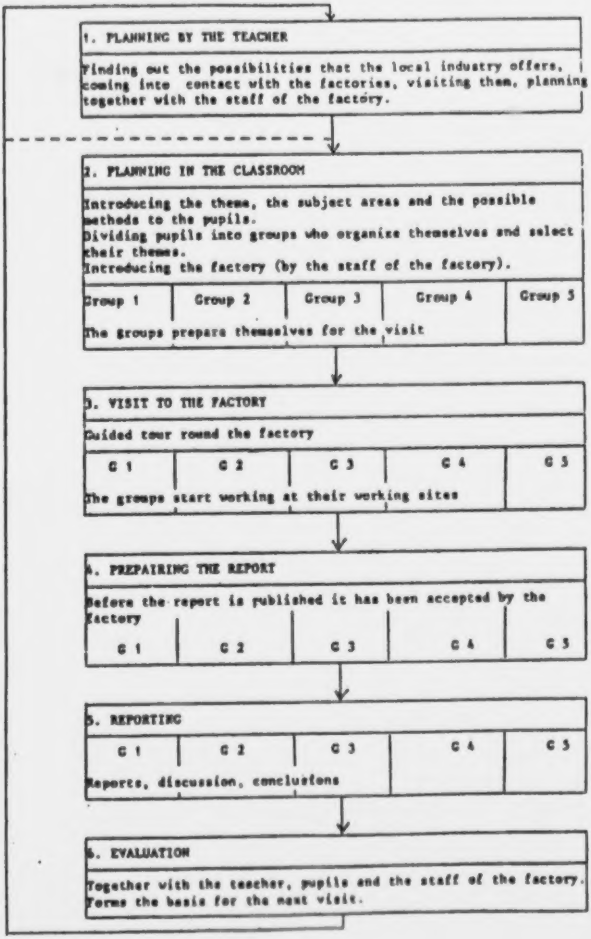
A visit can be divided into six phases:

1. Planning by the teacher and the staff of the factory
2. Planning in the classroom
3. Visit
4. Prepairing the report
5. Reporting
6. Evaluation

The model is described in figure 2.

4. Testing the model in the field

During the Heinola experiments an unofficial team was formed to guide the implementation of the model. In the team there were representatives of the National Board of General Education, the Chemical Industry Federation, the Association of Teachers of Mathematics, Physics and Chemistry and Kemira (a company in the field of chemical industry, consisting of a research center and nine factories in different parts of Finland). The team has met regularly, sharing information, discussing and consulting questions that are linked with the visits to factories. Initiated by the team there was a symposium where the representatives of the school and the industry evaluated this new form of co-operation.



1. PLANNING BY THE TEACHER

Finding out the possibilities that the local industry offers, coming into contact with the factories, visiting them, planning together with the staff of the factory.

2. PLANNING IN THE CLASSROOM

Introducing the theme, the subject areas and the possible methods to the pupils.
Dividing pupils into groups who organize themselves and select their themes.
Introducing the factory (by the staff of the factory).

The groups prepare themselves for the visit

3. VISIT TO THE FACTORY

Guided tour round the factory

The groups start working at their working sites

4. PREPAIRING THE REPORT

Before the report is published it has been accepted by the factory

5. REPORTING

Reports, discussion, conclusions

6. EVALUATION

Together with the teacher, pupils and the staff of the factory.
Forms the basis for the next visit.

Fig 2: The "Heinola-model" for the pupils' visit to industry

Kemira, which is one of the biggest enterprises in Finland, adopted the Heinola-model and trained the staff in all of its units to conduct these visits. The units have been active in offering an opportunity for the neighbourhood schools to visit them.

A questionnaire was sent to the 180 teachers who participated in the courses in Heinola. The letter and a follow up letter were answered by 122 teachers.

Among those who answered

49 % had organized one or more visits
24 % had not organized but are going to organize next year
27 % have not organized and are not going to organize visits next year

Of those, who have organized one or more visits 94 % are going to organize next year, too.

Altogether there were 109 visits to 81 different firms. The average size of a visiting group was 19 pupils, who divided into 4 working groups in average. One visit took in average 6 lessons.

One third of the visits fulfilled well the criterion of the Heinola-model, one third were traditional visits and one third were between these two cases.

5. Learning outcomes of a visit

Comparing the results from the visits with the task of the school, following conclusions have been drawn:

- Though the visit is oriented or designed to serve physics or chemistry, it must not be evaluated in the terms of the aims of subject alone, but the broad goals of education should be kept in mind.

- The visit motivates learning and gives variety to everyday routine. Pupils get a chance to meet adults other than parents and teachers.

- It is important for pupils to experience the interaction between theory and practice, to see how knowledge learned at school is applied in everyday life. Pupils learn more about their home neighbourhood, too.

- During the visit pupils will interact with the technical staff of the factory. This will enrich their knowledge of professions, from which they can choose their own career.

- An industry visit provides a natural opportunity to use alternative teaching methods and encourages pupils' independent, autonomous work.

- For teachers a visit provides an opportunity to become acquainted with industry. Teachers often learn as much as pupils.

- A visit will often be of value to two or more curriculum subjects. This leads to a natural co-operation among teachers.

The outcomes from a visit are presented in figure 3.

THE EDUCATIONAL OUTCOMES OF A VISIT TO A FACTORY

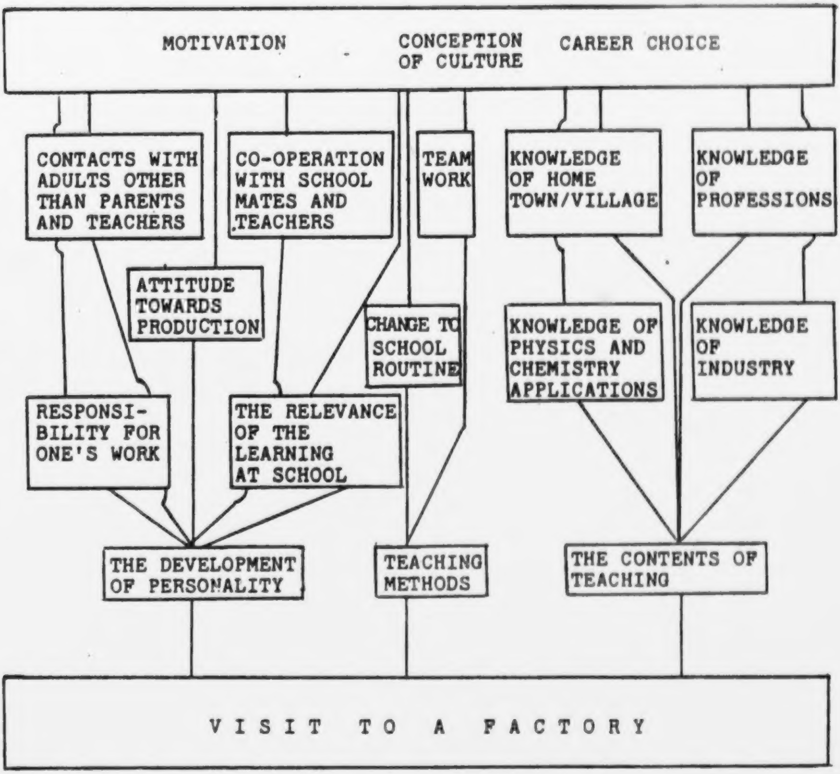

MOTIVATION
CONCEPTION OF CULTURE
CAREER CHOICE
CONTACTS WITH ADULTS OTHER THAN PARENTS AND TEACHERS
CO-OPERATION WITH SCHOOL MATES AND TEACHERS
TEAM WORK
KNOWLEDGE OF HOME TOWN/VILLAGE
KNOWLEDGE OF PROFESSIONS
ATTITUDE TOWARDS PRODUCTION
CHANGE TO SCHOOL ROUTINE
KNOWLEDGE OF PHYSICS AND CHEMISTRY APPLICATIONS
KNOWLEDGE OF INDUSTRY
RESPONSIBILITY FOR ONE'S WORK
THE RELEVANCE OF THE LEARNING AT SCHOOL
THE DEVELOPMENT OF PERSONALITY
TEACHING METHODS
THE CONTENTS OF TEACHING
VISIT TO A FACTORY

Figure 3

EXPERIENCES FROM TEACHING BIOTECHNOLOGY

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Introduction

Ole Heie has exellently made it clear to us, why it is important to deal with biotechnology in primary school.We have as Ole mentioned been working together to develope the teaching materials on "BIOTECHNOLOGY"

Before we started the work to develope the teaching material, we were eager to find an answer to the following questions:

- Are the students in the ninth and tenth grade sufficiently mature to understand the practical use of biotechnology on a reasonable level, (or will they take to science fiction with no substance in reality)?

We thought "yes", if they gained sufficient special knowledge to be able to attend to the public discussion.

- As for the teachers?Would it be possible for them, even with a certain biological background, to teach within the areas of biotechnology?

We thought "no".No, because biotecnology is so new to the public that available information primarily was, and still is, ment for people with certain special knowledge, and for scientists. Teachers were thus prevented from possessing themselves of the necessary knowledge.

Our purpose with the teaching material.

Our purpose was to develop a teaching material, which within reasonably short time would enable the teacher to gain the necessary knowledge - and along with that the possibility to pass this knowledge on to the students.We also hoped to inspire the teacher through ideas how to organize the teaching.

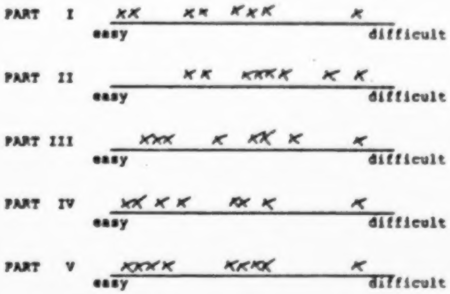
12 classes have been working with the material.

12 classes - partly from the neighbourhood of Copenhagen, partly from the provinces - have been working with the 2.nd. revised edition of the teaching material in the period of January to April 1985.

The teachers evaluation.

To give an impression of how this has turned out, I shall briefly give some of the conclusions of the teachers evaluation on the material and the students'/classes' reactions to the teaching.
(The entire evaluation is laid out to the public along with the teaching material during this conference).

HOW WAS THE TEACHING MATERIAL TO USE?



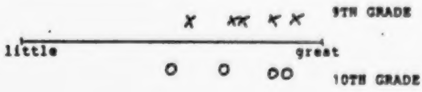
Part I: methodology
Part II: special knowledge - teachers level
Part III: special knowledge - students level
Part IV: collection af newspaper articles
Part V: teachers guide to the film "Children of the future"

(Each mark represents one teacher).
Generelly the teachers find the material fairly difficult. They would, if possible, like the technical literature to be further popularized.
Apart from that they are very content with the teaching material and the way we suggest the teaching to be organized.
As for the teachers level our purpose is obtained!
The teachers have found it interesting to work with biotechnology - but what about the students? How was their interest in the subject? Did they enjoy working with it? Did they find it too difficult? Etc.

The students'/classes' reactions to the teaching.

We asked some questions to the teachers in order to throw light on these points.

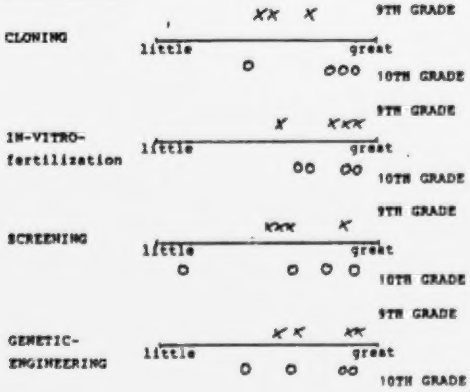
GENERELLY THEIR INTEREST IN THE SUBJECT WAS:



(Each mark represents a class)

The interest was above medium.

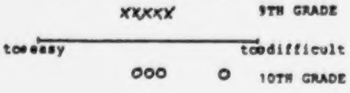
HOW DID THE INTEREST DISPERSE OVER THE VARIOUS AREAS OF THE SUBJECT?



(Each mark represents a class)

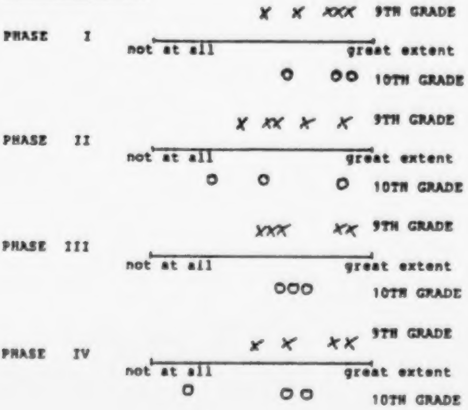
Teachers comment:"The theory of genetic engineering was most difficult for the students.Cloning and in-vitro-fertilization were found to be the greater interest".

GENERELLY THE STUDENTS FOUND THE SUBJECT:



The grade of difficulty was estimated to be medium/above medium.

TO WHAT EXTENT DID THE VARIOUS PHASES CATCH THE INTEREST OF THE STUDENTS?



Phase I: motivation
Phase II: special knowledge
Phase III: work in groups to deal with issues of importance to the community concerning the practical use of biotechnology.
Phase IV: phase of gathering/making product

Generally the interest was above medium in all phases.

WAS THERE ANY CHANGE IN THE UNDERSTANDING AND KNOWLEDGE OF THE STUDENTS DURING THE PERIOD?

Generally they displayed greater knowledge and understanding. Teachers comments:"Definitely.Generally they showed greater insight and understanding of the importance of the subject". "Yes - fortunately.Conceptions like in-vitro-fertilization, cloning, genetic engineering, surrogate-mothers found their way into the class room discussions".

"I felt in the discussions, that the students had gained large understanding of the problems (particularly concerning the ethics) which biotechnics force us to face".

WERE YOU ABLE TO FIND CHANGES IN THE INDEPENDANT ATTITUDE OF THE STUDENTS CONCERNING ISSUES OF THE PRACTICAL USE OF BIOTECHNICS?

The students showed a clear tendency to involve themselves and through this make up their minds.

Teachers commets:"Yes, many students took up a moral attitude as they realized the prospects".

"Yes, in particular many girls acted on the question of surrogate-mothers.They were far from reaching an argument on the point of law-giving".

IS IT YOUR IMPRESSION,THAT THE ATTITUDE OF THE STUDENTS CONCERNING GENETIC RESEARCH AND PRACTICAL USE OF THIS WAS MAINLY:

	NEGATIVE unsympathetic	QUESTIONABLE uncertain	POSITIVE appreciative	
			with certain reservation	without reservat.
CLONING EXL. MAN		X O		
CLONING INCL. MAN	X O			
IN - VITRO-FERTILISATION	O	O	X O	
GENETIC ENGINEERING EXL. MAN		X O	X	
GENETIC ENGINEERING INCL. MAN	X O			

X~ 9TH GRADE O~10TH GRADE

TYPICAL ANSWER.

We also asked IF THE TEACHERS FOUND THE SUBJECT RELEVANT TO THE 9th & 10th LEVEL.

Here the answer was - yes most relevant.

Our purpose was thus gained at the students level as well. The students not only obtained greater insight, many of them found an interest in the subject, which reached out beyond the work in school.
One of the teachers writes: "The students started reading articles in the newspapers, listening to radio and TV-programmes on the subject - and they told me about it".

Conclusion.

All - teachers as well as students - have found it interesting working with the subject - even if, at times, it was difficult. But all new is difficult.I suppose it is a question af time and a reasonable popularization of the special knowledge before biotechnics will settle in the minds of people - like the technics and use of computers.

But it is important, that the areas of biotechnics will not stumble into the world of school education, as was the case of computers here in Denmark.

(Along with the teaching material "BIOTECHNOLOGY", and the entire evaluation, I have allowed myself to exhibit a few examples of my book "Biotechnics and the future" here at this conference.The book is an attempt to make the subject comprehensible to "ordinary people").

RESEARCH INTO SCIENCE AND MATHEMATICS EDUCATION AT GÖTEBORG

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Background

A content-related pedagogical perspective has gradually been developed by the INOM-group Note 1), Department of Education, University of Gothenburg. This approach meant a break with the prevalent views claiming a quantitative approach to phenomena of learning. This shift of paradigm implies that the effects of learning cannot be quantified in "how much" but are qualitative in "what" and "how". The focus of *what is learnt* and *how it is learnt* brings about an emphasis on the content and the act of learning. Phenomena like knowledge, learning and teaching must be described in terms of the subject matter, i. e. the focus of the student's attention in a certain situation (Marton, 1975, Dahlgren, 1975, Säljö, 1975, Svensson, 1976, Marton, Dahlgren, Svensson and Säljö, 1977).

Characteristic of the work done by the INOM-group is the method of interviewing and analysing interview data. The method has been described in the works mentioned above and is continuously being developed. The interviews are trancribed and the protocols interpreted and analysed. Such an analysis will establish *categories of description*, concerning various conceptions of knowledge as the qualitative differences in conceptions of a certain content. These descriptions form an *outcome space of conceptions* and *forms of thought* about a certain phenomenon and form a result as such. Several studies have shown the productivity of this pedagogical perspective of knowledge formation, now called phenomenography (Marton (1981).

In the early 1970's, the formation was laid for a subject didactic theory for science education based on the Theory of Science and Research created by Professor Håkan Törnebohm, University of Gothenburg. Since 1975 we have continued this work within the INOM-group and a subject didactic theory for science and mathematics with a basis in empirical research on the Integrated Upper Secondary School, has been developed (Lybeck, 1981a). We have used the interview method developed by the INOM-group and the outcome of the interview studies has been employed as tools in describing and interpreting phenomena of learning and teaching, recorded in classrooms and school laboratories. This is a methodological development of the research approach of the INOM-group.

The theoretical reflections on our research approach in the field of science and mathematics education have been presented by Lybeck (1979a, 1980), and in Swedish by Lybeck (1978b, 1981a). Some empirical results on maths and physics are to be found in Lybeck (1978a, 1979b) and in Lybeck, Strömdahl and Tullberg (1985) on chemistry. The most coherent presentation of earlier theoretical and empirical results is to be found in Swedish by Lybeck (1981a). Unfortunately, most of our results are published in Swedish.

The status of teaching science and maths in Sweden has been described by Lybeck and Sjöberg (1984). The first research project was initiated on June 1st, 1975. At that time many of the students in the natural science line (N line) and technology line (T line) of the integrated upper secondary school (grades 10 - 13, ages 16 - 19) experienced a dramatic change in the way the world around them is percieved as a result of the transition from the nine-year comprehensive compulsory school. Physics and chemistry present abstract concepts that take a long time to understand. In spite of the fact that the students are interested in the natural sciences and mathematics, they are confronted by a way of reasoning that many of them have little experiences of; at the same time they are required to reason along very definite lines. Our question was:

> How do the students reason when they begin their studies in the N and T-line and
> what changes take place in their reasoning during their studies ?

We believe that partial answers can be given if one studies the way in which students reason when they are working with a certain subject content, i. e., a particular scientific phenomenon related to a principle or certain concepts, e. g. Archimedes' principle and the concepts of density and pressure. We have tried to describe the *students' qualitatively different conceptions of a phenomenon* at a certain point in time and during the teaching itself. The object of the studies consists of the spontaneously expressed qualitative *conceptions* or *thought forms*. The object of our studies cannot be found in textbooks or in the teacher since it is a *phenomenon* that acts as a *relation between* the *student* and the *subject content* or *phenomenon* studied by the student.

In the first place, examples will be given of the results obtained from interviews with individual students and from tape-recordings made in the classroooms and school laboratories. The extent of the findings in this connection will be commented upon and the problem area for didactic research will be shown.

N and T-students' conceptions of the concept proportionality

The concepts of proportion and proportionality are taught in the compulsory school, and proportionality is taught again in grade 10 (first grade of the upper integrated secondary school). These concepts are used as *mathematical instruments* in the formation of concepts such as density, speed, resistance, amount of substance and concentration, and concepts such as some of those included in the chemistry and physics syllabi in grade 10 of the N and T-lines. Our main interest was:

How do the N and T-students quantify using those concepts ?

As our studies were concentrated on the age group 16 - 17 (grade 10), we also used the Measuring Cylinder Task and the Spring Balance Task (Suarez, 1977(1975)). We will exemplify the *outcome space* of the N and T-students' conceptions of the concept of proportionality with the Measuring Cylinder Task without touching on the actual interview procedure (on the procedure, see Lybeck, Strömdahl and Tullberg, 1985, p 163).

The Measuring Cylinder Task

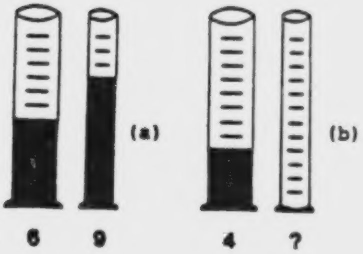


Figure 1: (a), starting-point in the Measuring Cylinder Task, and (b), question 4-y

Identically graduated measuring glasses with different diameters are used. The scales are not numbered, nor is any unit of measurement given. First, the interviewer fills the "thick" cylinder with water up to level '6'. When the water is poured into the "thin" cylinder it rises to level '9' as shown in Figure 1 (b). This is the starting point for subquestions as those:

Question 4-y: If I pour water up to 4 level of the thick cylinder, how high would it come in the thin cylinder (which is empty) ?

Question 9-y: If I pour water up to 9 level of the thick cylinder, and then pour the water into the empty (thin) cylinder, how high would it come ?

The answer is followed up by:

How did you work it out ?

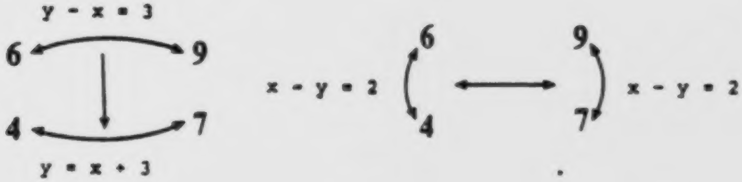
Well, how would you, dear reader (teacher), reason when you solved the problem ?

This is how the students 5N and 4N (N line, girl and boy) answered:

S: Well, I thought like this, the difference
between 6 and 9, then I thought, (y - x = 3)
and so 'plussing', adding... you add
it, the difference to 4. ... 7. (y = x + 3)
(5N)

S: 7.
E: How did you arrive at that ?
S: 6 minus 4 is 2. (x - y = 2)
9 minus 7 is 2. (x - y = 2)
(4N)

Our algebraic interpretation is given after the students' answers. We use x and y in the conventional sense as first and second term in the pairs of values (x, y). The students arrived at the same answer but used completely different solving strategies which we have described symbolically as follows:



(Student 5N) (Student 4N)

Figure 2: Solving strategies used by students 5N and 4N answering question 4-y

The outcome space of students' conception of proportionality

It was found that the best interpretation of a nuanced, empirical body of material is provided by a general line of thought which reflects the *concept of function* and an interacting conception of how quantification should take place. The *functional aspect* is the students' line of thought on the conception of the proportion and proportionality tasks, with the answer categories A and B. The *quantification aspect* stands for the way in which mathematical instruments are applied and has four categories, 1 - 4. Thus, student 5N quantifies *between* the relevant variables (*A form*) and student 4N *within* one variable at a time (*B form*).

Within each of the function aspect's category of answers A and B, the students express the changes that have taken place in different ways. We also find, however, the same mathematical instruments among the answers categorized as A or B forms. Below are the four categories of answers referring to the quantification aspect.

The quantification aspect

1. Direct proportion. The relationship is expressed as a multiplication or a division or as a relation (ratio), e.g. as in

   $y = 1.5 \cdot x$ or $\frac{y}{x} = \frac{3}{2}$

   or inverted as in

   $x = \frac{y}{1.5}$ or $\frac{x}{y} = \frac{2}{3}$.

2. Proportional increase or decrease. The relationship is expressed as an addition, subtraction or difference with the aid of a (increment) factor or ratio, e.g. as in

   $y = x + \frac{1}{2} \cdot x$ or $y - x = \frac{1}{2} \cdot x$ or $\frac{y - x}{x} = \frac{1}{2}$

   or inverted as in

   $x = y - \frac{1}{3} \cdot y$ or $y - x = \frac{1}{3} \cdot y$ or $\frac{y - x}{y} = \frac{1}{3}$.

3. Relating either absolute increase, absolute decrease, or absolute difference.
   The student realizes that the increase, decrease, or difference cannot be absolute (see category 4 below), but does not succeedin quantifying the relationship in categories 1 or 2 above.

4. Quantification through absolute increase, decrease or difference.
   The relationship is seen as an addition, subtraction or a difference as in

   $y = x + 3$ or $y - x = 3$

   or inverted as in

   $x = y - 3$.

Note that student 5N utilizes the form in the relation that *explicitly* expresses the number she wants to obtain. Student 4N, on the other hand, does not change forms when he applies the relation for the second measuring glass and consequently does *not explicitly* express the unknown size. These ways of quantifying belong to answer category 4. The *thought forms* used by the students are called A4 and B4 in the *two-dimensional table of categories* which the *outcome space* constitutes.

At the beginning of the school year, four students answered question 4-y with the A4 form and one out of 26 with the B4 form; at the end of the school year, nine students out of 76 answered the question with the A4 form. In spite of one school year's study, to spontaneously express the 'corrective' reflection: 'If I pour water from the empty thick cylinder into the thin one, then it will be filled up to the third scale line' does not come naturally to these students.

From a methodological viewpoint it is important to note the essentially different thought forms illustrated by answers in the A or B category of the function aspect. Category A leads to the algebraic form $y = 1.5 \cdot x$, i.e. the general functional relationship for direct proportionality, while category B leads to quantitative algebraic forms that do not express any general direct proportionality. This constitutes *didactic knowledge* that is of great importance to concept formation in the natural science subjects, where relevant variables of different qualities (quantities) lead to the new concepts by means of the A1 form. It is the A1 form that holds development potentiality.

We cannot do the students justice in this paper by presenting the wealth of thougt forms used by them, but must instead refer to the reports of the BMN project.[Note 2)] In conclusion, however, let us illustrate how student 3T describes the inverse thought form ($x = \frac{2}{3} \cdot y$).

> S: There is two third in the large... of what will be
> in that one (the thin one).
> (3T)

However, he solves question 9-y with the A2 form $y = x + \frac{1}{2} \cdot x$, probably because of the arithmetic complexity that arises when the thought form in A1 is retained.

The students' responses on the Measuring Cylinder Task and the Spring Balance Task can be described by the same two-dimensional outcome space with the same basic structure. In fact, no responses were obtained in the A2, A3, A4, and B4-cells of the outcome space of the Spring Balance Task.

Here, there is reason to reflect on the relation between the outcome space and other knowledge production involving the concept of proportionality. Our qualitative analysis shows that the functional aspect's A and B forms are descriptive categories that are superior to the quantification forms 1 - 4. In studies in developmental psychology and in mathematics and science education, the functional aspect is not used as a descriptive category; however, the quantification aspect shows similarities to our results (Lybeck, 1981a,b). As in the case of our studies, the aim of these studies has been to map the formation of scientific concepts related to the concept of proportionality. Using A and B forms has made it possible to discuss the results of other researchers as well as to show that the outcome spaces are a stage in the process of learning about students' thought processes (Lybeck, 1981a,b). Here, it is a question of research methodological matters concerning the validity and reliability of the results.

Inhelder and Piaget (1958) use the so-called INRC group to psychologically explain children's ways of thinking about direct and inverse proportionality. Their theory does not distinguish between the A and B forms that can be found in their empirical data, e.g. on the two-arm lever (pp. 173-181). Our A and B forms thus constitute negative evidence in the case of their theory.

We have found that while one student may solve the Measuring Glass Problem by using the A form and the Spring Balance Problem by using the B2 form, another student may well do the opposite. According to exponents of Piaget's theories, a student is a formal thinker if he uses A1 forms and a concrete thinker in other cases. With this classification, our students would be formal thinkers with proportionality in one context but not in another. In our view, this is not a suitable way of classifying students. It is not really relevant to knowledge of students' thought processes as a basis of teaching and learning. We do, however, feel that it is an appropriate method to describe the conceptions and thought processes manifested when students encounter different types of content where proportionality is a part of comprehending a phenomenon. It is the content of the students' way of thinking about a phenomenon that we are trying to classify.

The functional concept of mathematics have been developed over a long period of time in relation to physical phenomena. When Galileo Galilei quantified the law - arrived at by means of experiments - govering the relation between distance and time in the case of balls rolling down an inclined channel, he used proportion and the B form. In his time, algebra had not been developed into the form it has today. It was first during the latter part of the 17th century that Leibniz and Newton used proportionality in the modern sense of the word. Freudenthal (1978) discusses in depth ratio and proportion in his didactic phenomenology. He exemplifies with the uniform velocity:

> "'In equal times, equal distances are covered' is a popular definition; and this is, if continuity is tacitly assumed - as it should be - equivalent to the formally stronger statement 'distances are in proportion to times'". (p. 293)

Ratios formed by pairs of numbers in a system are called internal and corresponds to the B form. External forms corresponds to the A form. In the case of uniform velocity, we have - using Freudenthal's symbols - the following thought forms (knowledge forms):

"$s_1 : s_2 = t_1 : t_2$" (B1 form)

"$s_1 : t_1 = s_2 : t_2$" (A1 form)

Freudenthal also says:

> "Interchanging the middle term in a proportion is so familiar to us that we can hardly realise the width of this mental jump. ... and since today nobody is aware of this mental jump, nobody raises the question whether it could not be too big for the learner." (p. 294)

It is obvious that Freudenthal has made use of this insight when improving textbooks. He has not, however, shown by means of empirical studies that this difference in external and internal relationships is to be found in students' conceptions of the above-mentioned concepts.

A point here is that the A and B forms have their equivalents in the history of mathematics and science. This strongly supports the plausibility of the outcome space arrived at by means of subject-didactic studies in these fields. The outcome space reflects the nature of the thought processes that both characterized these fields of knowledge. The dominating thought processes represented by the A and B forms can with good reason be called styles of thought.

It is obvious that other disciplines, in addition to developmental psychology and educational psychology, can make substantial contributions in the form of humanistic knowledge of importance to subject-didactic research. Such disciplines are theory of science and history of science and ideas. In the case of mathematics, the outcome space should contain the knowledge in this field. Our forms corresponds to a property of 'the function proportionality' which mathematicians write as follows:

$$f(k_1 \cdot x_1 + k_2 \cdot x_2) = k_1 \cdot f(x_1) + k_2 f(x_2).$$

A criterion of an outcome space arrived at being a contribution to subject-didactic research is that teaching problems can be discussed with the help of this outcome space. When describing a relation, the student can choose two different references, one for the 'growth' factor and one for the increase. (In the Measuring Glass Task, the A2 form $y = x + \frac{1}{2} \cdot x$ leads to the correct answer, but some students use a strategy to solve the problem which can be expressed by $y = x + \frac{1}{3} \cdot x$; $\frac{y - x}{x} = \frac{1}{2}$ and $\frac{y - x}{y} = \frac{1}{3}$.) This is a common error when calculating percentages and can partly be explained by the fact that the students prefer the way of thinking that explicitly results in the number searched for when quantifying.

The two-dimensional out-come space for proportionality can be used for subject-method hypothetical reasoning about how students solve proportionality tasks related to different subject contents (Lybeck, 1981a,b). I would like in this way to indicate a possible way of constructing a model that takes into acount the contextual dependence in the students' thought processes. It would also take into account the widely varying ways in which they reason. The aim here is, quite simply, to convert thought content into teaching content. Another example of subject-method hypothetical reasoning based on the A and B forms is the explanation of how pupils reason when carrying out operations with the position of the decimal-point. In fact, this operation means that an A form is used, but the pupil can use a B form and thus avoid the more abstract A form.

Textbooks can be analysed with the help of the outcome space. An example is given of how the teaching method is based on B forms in the general course while A forms are utilized in specialized course programmes when it comes to applying the concept of percentages in mathematics teaching at the upper level of compulsory school (Lybeck, 1981a). The way in which a textbook presents a starting-point for teaching is one thing, but the way in which this starting-point is made use of in teaching is a different matter entirely. If the students do not understand when using the A form, the teacher risks leading them into a cul de sac by using the B form. I have called this phenomenon of teaching metod piloting.

Initially, our proportionality study concerned N and T students at the beginning of their first year at upper secondary school. It can be seen primarily as a qualitative evaluation of mathematics teaching at compulsory school level given to this special group of students. By carrying out interviews with the help of this instrument, which is made up of the outcome spaces for the proportionality tasks, quantitative effects of teaching can also be evaluated. We thus obtain a different frequency distribution at the end of the first year which shows that the students' numerical skills have improved (Lybeck, 1981b). Alterations in the syllabus of mathematics during the 1970's were intended to achieve this effect.

The two-dimensional outcome space has also been used by teachers as a diagnostic instrument (Lybeck, 1981b).

Using the same phenomenon, it is possible to describe students' conceptions that differ from each other. This can have consequences when the categories of description obtained are used as instruments of evaluation. Consequently, an important question as regards subject didactics and didactics in general concerns taking into consideration differences in the perspectives and underlying assumptions that effect the formation of knowledge (Lybeck, 1981a,b). This is also a question of methodological research issues which is not only limited to the validity and reliability of the evaluation instrument but also, to a larger degree, to its relevance. This, when research results are to be used as the basis of arguments for or against certain measures to be taken in work on syllabi and curricula, great attention must be paid to these aspects.

Here, I would like to describe the outcome space for students' conceptions of the quantity density.

Students' conceptions of density

The Cartesian diver (Figure 3) was used in interviews with individual students from the N line, first year, the two-year social science line (So line), first year, and the upper level of compulsory school, first year (grade 7).

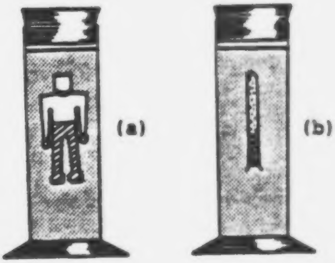


Figure 3: The Cartesian diver (a) and a model of the diver (b)

The physics-based explanation of the Cartesian diver phenomenon entails system thinking. The system consists of the following subsystems: the diver, the water in the outer pipe and the earth. The diver interacts with the surrounding water and the earth. A complication is that the diver subsystem also consists of subsystems; these are: the glass object itself, the volume of water and the amount of air in the glass container at a given time. At the interviews, a model of the Cartesian diver (Figure 3, b) was used. This model accentuates more schematically the important subsystems.

The Cartesian diver phenomenon induces the students in a natural way to answer the question:

Why does an object float or sink in water ?

At the interviews, the students expressed conceptions of Archimedes' principle and density. Other related terms used by the students in their explanations were displaced volume (of water), lifting power, pressure, etc.

Three qualitatively different conceptions of density emerged from the qualitative analysis of the students' answers to the question above.

Category 1: Classifying

The explanation given is absolute in character and is characterized by the attention paid to one subsystem and one of its properties. The objects are classified as floating and not floating, i. e. sinking objects.

The students say that an object sinks because it is heavy, or that it floats because it is light. This can be due to a property of the water that enables it to "support" the object,

e. g. by means of the water's "lifting force" or its "surface tension".

Category 2: Comparative

The explanations given are in a sense relativistic and focus on two subsystems or two varibles that simultaneously express the properties of these two subsystems. The students see a comparative relationship between the proporties of the subsystems, e. g. the weights, masses or volumes of the subsystems.

The students say that an object sinks because it is heavier than water and that it floats because it is lighter than water.

A student can understand that two similar volumes of the subsystems are compared, but this is not expressed explicitly. The student can have an understanding of the concept of displaced volume and a clearly expressed statement on this relationship constitutes an example of the next category of description.

Category 3: Quantitative

The explanations given are characterized by the fact that the students try to quantify the realtionship between properties of the subsystems in the form of relevant variables.

An important element in this conception of density is the realization that the masses should be compared or, as the student say, that the weights of equal volumes of the object and the water should be compared. This realization is essential to the understanding of Archimedes' principle by means of the concept of displaced volume. A reporter in the TV news programme Rapport gave the following explanation of Archimedes' principle, which is not what the principle stands for from the point of view of physics:

> "... a body immersed in water displaces exactly the same amount of water as the body's own volume. This law is called Archimedes' principle." (Lybeck, 1981a, p. 194)

A quantification can mean that an object sinks because a volume of water equal to the volume of the object weighs less than the object. This is a B form conception of density according to the outcome space of proportionality. A quantification can also mean that the students say in some form that an object floats if the ratio of its mass to its volume is lower than the corresponding ratio for water (= 1 (g/cm^3)) and that it sinks if the ratio is greater than 1 (g/cm^3). This latter type of quantification is an A1 form. Characteristic of the most developed conception is that a quantitative relationship is formed between two varibles of different qualities, namely mass (m) and volume (V).

The categories of description from the classifying via the comparative to the quantitative category express a development that reflects the formation of knowledge in physics. A fitting example is the classification of objects as insultors and conductors (non-insulting) in electricity.

Our studies of students' conceptions of proportionality in the case of the Measuring Glass and Spring Balance Tasks demonstrated that an integration of the outcome spaces took place as a result of a degree of structural similarity. Similarly, we can see that the outcome spaces of the students' conceptions of density and proportionality can be integrated and I shall now exemplify this with excerpts from recordings made in classrooms and school laboratories. The two-dimensional outcome space has been used as an *analysis instrument* in studies of the transcriptions of recordings of lessons.

Integration of the outcome spaces for density and proportionality as well as recordings made in classrooms

At the beginning of the school-year, grade 10 of the N-line, a diagram was placed on the overhead projector (Figure 4). The diagram was based on the students' own data. They had measured the volume and mass of some wooden blocks (two different kinds of wood were used, but the students were not informed of this).

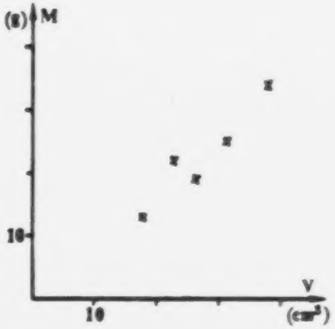


Figure 4: The teacher's diagram on the overhead projector

Teacher:	How did you react when you saw these points ? Perhaps you placed your points differently from mine.
Tor:	Well, you try to get them to appear symmetrical, or something like that. A straight line.
Jarl:	Try to get a straight line passing though the points... It's a bit difficult... You could try..
T:	What are we trying to get ?
Annie:	A relation.

Teacher: Between what, then ?

Olof: Between the points.

Astrid: The relation between volume, size and mass.

Tor: If you try to get a relation, then, so that the volume and the mass increase by an equal amount in comparison with each other.

But, of course, there are so many things that mean that it doesn't have to do that. So that those pieces of wood, they could be different types of wood, and they might have been taken from different parts of the tree. So that there are larger fibres and that sort of thing in the piece of wood. That means that they don't have to corresponds, but one tries to get the...

Teacher: So you aren't at all surprised that it's like this?

Tor: Well, I suppose I'd counted on it being a straight line.

Students: (Mumbling). Two straight lines.

Teacher: Why had you expected it to be a straight line ?

Tor: Yes, I had expected a result that showed that there really was a relation here between volume and mass. This, if this is what it's like on that (the diagram on the overhead projector), then you're not really getting anywhere. It's just like that. That's how it is. (Lybeck, 1981a, pp. 92-93)

The students had previously discussed their diagrams and talked about a relation as a straight line; but they had not drawn the straight line. Tor understands the functional relationship: "the volume and the mass increase by an equal amount in comparison to each other". This is interpreted as a B form (Figure 5).

$$\begin{tikzcd}
\text{Volume} & \text{Mass} \\
V_1 \arrow[dd, bend right, leftrightarrow, "{\text{``equal amount''}}"'] & m_1 \arrow[dd, bend left, leftrightarrow, "{\text{``equal amount''}}"] \\
{} \arrow[r, leftrightarrow] & {} \\
V_2 & m_2
\end{tikzcd}$$

(B form)

Figure 5: Tor's conception of the functional relationship volume - mass

The teacher later asks if there is any difference between the relationship mentioned by Tor and the relationship mentioned by Annie.

Annie: But it's like Tor said, you have to measure the mass and the volume and see if they agree more or less. (Mubling).
Teacher: You must explain more clearly.
Annie: Yes. But that the mass and the volume. Even if the mass is... The mass must be equally large as the volume. They must agree, even if the bits are different sizes (have different volumes).
Teacher: Once more, Annie. That sounded interesting. The mass and the volume must be equally large, even if the bits are different sizes.
Student: The density.
Annie: Yes, the density must (be equally great).
(Lybeck, 1981a, pp. 96-97)

What is "equally large" is clearly the relationship between mass and volume at each point in the diagram and this relationship is called density. If this interpretation is correct, then the verbal quantification is equivalent to an A form of the functional relationship. Figure 6 shows how this can be symolized.

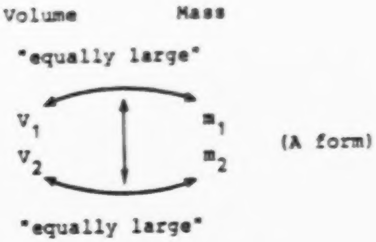


Figure 6: Annie's conception of the functional relationship volume - mass

During a lesson, the teacher initiated a discussion between the students by placing two boxes, covered with tinfoil and sealed with tape, in a bowl of water as shown i Figure 7. The boxes appear to be equally large but one of them sinks more deeply into the water. They both have their largest base areas parallell with the surface of the water.

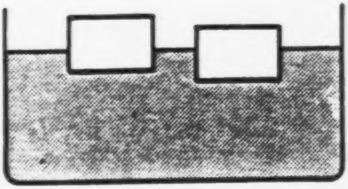


Figure 7: Two boxes floating in water

The above qouted student Tor responded as follows:

Tor: Well, if you take the bit that's under water you can measure it and see what its volume is. And then you get, for example, 3 cm^3. So it has displaced 3 g of water, and then you measure the rest of the piece above the water to see how much of it there is. So if one says that 1/3 is under water, then one has to take that weight times 3 in order to get the weight of all of it.

And: No.

...

Teacher: They want you to repeat what you said.

Tor: Yes, but the part of the box that is below the water surface has a certain volume then, say 3 cm^3. And so 3 cm^3 of water is displaced. That'll be 3 g of water too. Then there's the part that's above the surface of the water. One has to calculate a percentage of how much is below the surface in order to get the whole, and then it weighs 3 g, the part under the water. Then, there's the rest... then one knows what a part of the box weighs and all one has to know then is how large the part is one has weighed.

E: May I ask whether the part which is below the surface of the water is 1/3 of the whole (box) ?

Tor: Yes.

E: It weighs 3 g, you said.

Tor: Yes.

E: That was your example ?

Tor: Yes.

E: How much does the whole box weigh ?

Tor: It weighs 9 g, then, yes.

E: I see.

...

Van: That can't be right.

Teacher: Do you agree And ?

We interpret Tor's conceptions as follows. He perceives the concept of denisty in the B1 form (Figure 8).

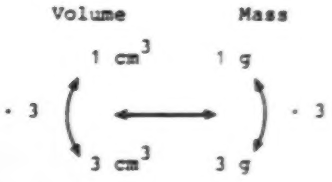


Figure 8: Tor's conception of density in B1 form

This qualitative conception of the concept of density brings to mind the concept 'specific weight' as it was known in the 13th and 14th centuries, which is the weight of an appropriately chosen volume in an experimental connection. There is, thus, a conceptual distinction between weight and specific weight; they are, however, measured in the same physical dimension, namely, weight in this 'Aristotelean world of conceptions'. In this hypothetical experimental context, Tor makes this assessment with B1 forms according to our interpretation. Firstly, a perceptually estimated volume, and finally to the object's total weight (in air). (See Figure 9).

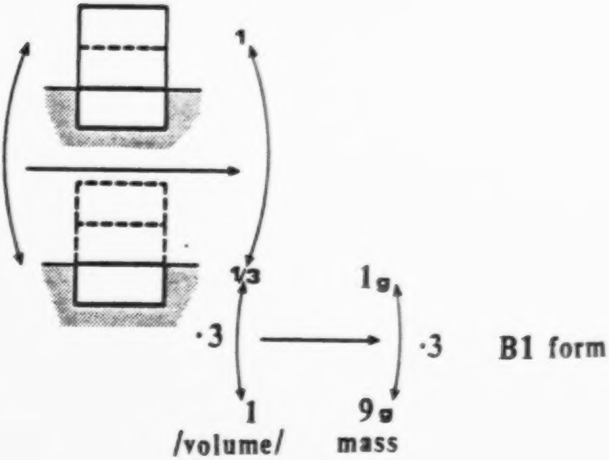


Figure 9: Interpretation of Tor's conception

Tor was completely convinced that the 'strength in the interation' between the subsystems 'water' and 'floating objects' is a measurement of the part of the object below the surface of the water. The researcher's (E) questions are an example of how empirical evidence is generated in order to confirm the didactic hypothesis regarding Tor's qualitative conception of the phenomenon. Some of his classmates disagreed with him. They tried to make him abandon his conception by means of different arguments but he remained stedfast to his 'theory'. The cognitive conflict created in Tor and several of his comrades was solved the next day when they discovered Archimedes' principle, which was then formulated in a more suitable way from the point of view of physics, by means of experiments planned and executed by them.

Tor: The weight of the object is equal to the weight of the displaced water.

We should note that Tor's "theory" according to Figure 9 is a step in a refined process that can lead to the introduction of an areometer, a density meter for fluids. When do the students use their own spontaneously constructed conceptions of measuring instruments in the instruction ?

The didactic problem which Tor and his teacher helped us to formulate has been given to several classes at the senior level of the compulsory school, grades 7 and 8. Here is a similar extract from a recording made in grade 7 at the beginning of the spring term after the concept of density had been introduced.

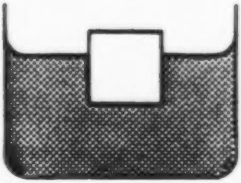


Figure 10: Breaker filled with water and floating wooden block

Teacher: ... You are to estimate how much of it sinks ?
Rolf: About three fourth.
T: Three fourth, yes. Three fourth below the surface of the water, one fourth above. Is there anyone who can say what the density of the wood is, then ? What is the density of the piece of wood ? This contains ordinary water now (the breaker).
Rolf: 1.25.

T: How did you reason ?

Rolf: I reasoned, but I reasoned incorrectly. But I reasoned that the water had 1 g per cm^3 in density, so the wood had 1/4, well, I should say less.

T: Hm. The wood had 1/4 less, you said. What would it have been then ?

Rolf: 0.75 g. (N.B. He does not say g per cm^3.)

T: 0.75. What would have happened if the piece of wood had had a density of 1.25 ?

Bo: It would have sunk.

We have interpreted Rolf's thought form symbolically as follows with the analysis instrument based on the students' proportion and proportionality way of reasoning. (See Figure 11.)

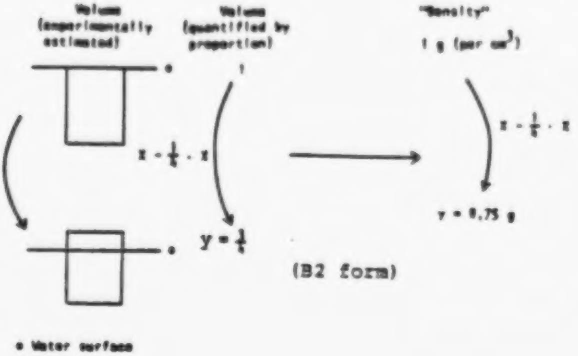

Volume (experimentally estimated)
Volume (quantified by proportion)
"Density"
1 g (per cm^3)
*
1
$x - \frac{1}{4} \cdot x$
$x - \frac{1}{4} \cdot x$
*
$y = \frac{3}{4}$
$y = 0.75$ g
(B2 form)
* Water surface

Figure 11: Interpretation of Rolf's conception

It is probable that Rolf means the weight of a certain volume chosen for the purpose, namely, 1 cm^3, when he says "1 g per cm^3" density. He has quantified with the B2 form. We note that he still understands the concept of density in a B form and evidently not in an A form as his first statement could have been interpreted from the perspective of physics.

Which concept of density do the students take with them to the upper secondary school ? Surely, density is expressed in A1 form $\rho = \frac{m}{V}$ at the senior level ? This is certainly the case, but as our recordings from the senior level show, the concept is given a meaning mainly in the B form.

It is very interesting to note that the results based on Tor's problem are possible to recapitulate for much younger students.

After a teacher has introduced the concept of density in A1 form in a class, grade 7, at the senior level of the compulsory school, the teacher and the pupils jointly solve a couple of density problems. In a concrete example, the mass was 200 g and the volume 20 cm^3 and in another 70 g and 10 cm^3 respectively. One pupil thought that 200 should be divided by 20. At this point, we join the conservation:

S:	It's per cm^3.	(Invitation to A1 form ?)
T:	Yes, I'll work out how large the mass is for each cm^3. What is the mass of 1 cm^3 in the first case, then, with this object ? (200 g and 200 cm^3 respectively.)	(B form for the density.)
S:	10.	(The B form does not require the implied unit to be stated.)
T:	Yes, it will be 10 g per cm^3,	(The pupil's B form is met by an A form from the teacher ?)

T:	as I usually express it. Each cm^3 has a mass of 10 g.	(The techer explains in the B form.)
	What comparison figure do we get over there ? (70 g and 10 cm^3 respectively.)	
S:	7 g per...	(The unit cm^3 disappears from the 'denominator' since 1 cm^3 is implicit in the B form.)
T:	It get 7 g. The other object weighed 7 g for every cm^3.	(The B form is established.)

In order to avoid any misunderstanding, we would like to mention that the B form is naturally not an incorrect thought form. In fact, it has been used as a form of knowledge in physics. The problem is rather that this qualitative conception is not as fruitful as the A form has shown to be in modern physics. The teacher is quite correct when he uses B forms for the concept of density, and "for every" is a correct model to use. But one should not leave it at that in the belief that it provides an understanding of the concept in the A1 form. In such a case, the pupil will be faced with a blind alley with regard to concept formation. (We wish to note the discussion by Arons (1976).) We invite the reader to make his/her own interpretation of this dialogue below which has been taken from a context that cannot be given full justice here. The teacher concludes the section with the following words:

T:	Now we have arrived at the point where we shall compare equal amounts. And I have also 'developed' it so that we have obtained a measure here of what	(The appropriate volume: "for every".)

T: the mass of 1 cm^3 is. And it is the comparison figure. We usually call it density, which is what so many of us here have been talking about.

When the teacher says 'equal amounts' he means quite simply equally large volumes, i. e., the appropriate chosen volume in comparisons between different matters. The expression can give rise to discussions on the interaction between chemistry and physics teachers. The measurement obtained in the form of a comparison figure (note figure) is the density in the B form, namely, 'what the mass of 1 cm^3 is'. The teacher has built up a teaching method strategy without knowing about the A and B forms. His great experience has shown him that pupils acquire a certain lasting understanding of the concept of density if B forms are used. From the teacher's perspective, his teaching functions satisfactorily. During laboratory lessons when the teacher walks about talking to groups of pupils, he explains his didactic conception to some of the pupils without having the observer's knowledge at the time of the experiment itself. We reproduce the following:

T: Yes, I would probably want to have the last one. Volume divided by mass; if you learn it by heart, you may quite simply not be able to remember it after a couple of months - was it volume divided by mass, or - mass divided by volume. What is important is that you learn to understand it all. What do we mean by saying that we want to find out about density ? Well, density is, to extract a small volume unit of 1 cm^3 and then one can obtain its mass, that is, 1 gram.
If you understand this, you know that you must always divide by the volume, that's the point, the point is to come down to one cubic centimetre (1 cm^3) and see what it weighs ?

S: What you get, then, is the density, isn't it ?

T: Yes, it's the comparison figure between the different types of matter.

S: Then for us the density was 3. (Note, that the pupil does not use a unit, which is implicitly understood using the B form of density.)

We have attempted to illustrate by means of the examples given above the learning and teaching phenomena from actual teaching where the student, the teacher and the student - teacher interaction has shown the phenomenon of the students' concept formation. The examples refer to the levels I and II in the model of the subject didactic problem areas in the next section.

Model of subject didactic problem areas

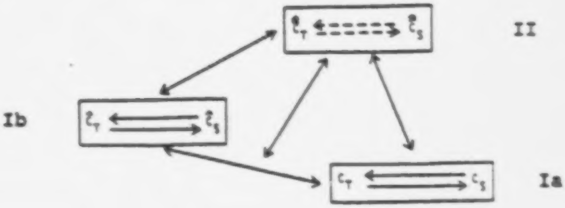


Figure 12: Model of subject didactic problem areas.

C stands for conceptions at different levels and can be divided into one part for the student (C_S) and another part for the teacher (C_T) at each level.

⇄ stands for a dialogue and ⇠⇢ for a less developed dialogue between teacher and student.

⟷ denotes relationships between the different parts of the conceptions.

Using only a few concepts, the model tries to illustrate a simple and intelligible division of the cognitive world which, in our research, applies in everyday physics, "school physics" and physics (and in a similar way for other subjects such as mathematics, chemistry, biology as well as for other subjects, e. g. history). In our case, students' conceptions (C_S) of density, proportionality, speed, resistance, function, concentration, amount of substance, etc. at level Ia are studied. In a dialogue, the students here encounter the teacher's conceptions (C_T) of the same concepts. At level Ib, we have the students' ($\bar{C}_S$) and the teachers' ($\bar{C}_T$) conceptions of concepts such as hypothesis, instrument, problem, data, experiment, etc. At this level, the students plan and criticize the ideas they produce. The levels Ia and Ib, which are subdivisions of level I, corresponds to the teaching content in accordance with the goals laid down in curricula and syllibi, namely information and knowledge of central concepts and of the procedures used in physics or chemistry. Level Ib can be said to reflect the teaching process.

Both ,teachers and students reflect on the content of the teaching at levels Ia and Ib. Those reflections belong to the model's level II. Here, we find the teachers' ($\bar{\bar{C}}_T$) and the students' ($\bar{\bar{C}}_S$) knowledge, knowing and opinions of teaching, learning and manners of working as well as traces of their views on knowledge that are developing. At level II, we also have concepts such as motivation and interest. In my opinion, the dialogue at level II is not as well developed as it is at level Ia and Ib. It is at level Ib that knowing of the manner of working is developed.

It is at level II in the model that the teachers' and the students' subject-teaching method conceptions of teaching, learning and knowledge are reflected. It is knowledge of this problem area at level II and its relationships to levels Ia and Ib as well as the relationship between Ia and Ib that is central to the teacher training.

The model makes explicit the need to map the process of reflection on level II employed by teachers, trainee teachers and school of education lecturers in teaching methods. In our opinion, knowledge of such conceptions constitutes central parts of the scientific content that should be included as part of the basis of teacher training. It is the knowing and experiences at level II, which are related to the other levels, that should be refined into knowledge and, indeed, should be made more disciplined in Sweden.

The compulsory school teacher in the previous section expressed thoughts belonging to level II in the model. Lybeck, Strömdahl and Tullberg (1985) have presented a chemistry didactic study of N-students' conceptions of the quantity amount of substance and its SI-unit 1 mol. We have also interviewed trainee teachers, teachers, school of education lecturers in teaching methods and authors of textbooks and presented them with the same task as posed to the N-students. During these interviews we asked questions about subject method and subject didactic conceptions of teaching the above-mentioned quantity. There is a student - teacher relationship between trainee teacher and lecturer in teaching methods. Similarly, we can, as in Figure 12, use a model with the aim of studying chemistry didactic problem areas in teacher training. If the model in Figure 12 can be described as concerning "thoughts about students' thoughts", then it should be possible to describe the latter model as concerning "thoughts about thoughts about students' thoughts". Knowledge of the last-mentioned "thoughts" is also a part of subject didactics and forms the basis of what lecturers in teaching methods should be proficient at. A lecturer in teaching methods must have other knowledge and skills, apart from being a good school-teacher.

The curricula's goals express a holistic view of the students' intellectual and social development. Our contribution in the form of the levels Ia, Ib and II should be expanded by the addition of an integrating level III in our model. In the preparatory work on the curricula and syllabi, goals for teaching and learning are laid down; these are value statements that can not always be scientifically proved. Subject didactic studies of the type we have carried out can contribute with results that may lead to alternations and more precise definitions or new goals for teaching as a result of our being able to show empirically that certain goals, not made explicit previously, can be attained.

One aspect I would like to mention as regards the development of subject didactics as a discipline, since it is still in its infancy, is that one chooses *strategically* suitable *research problems*. In our research, we have chosen the concept of proportionality which is *vertically integrating* through the grades from compulsory school to upper secondary school in mathematics. The concept of proportionality is also *horizontally integrating* over several subjects, e. g. in the first year at upper secondary school, as examplified above.

At the integrating level III in our model of subject didactic problem areas, subject didactic studies can be carried out related to general didactics and education.

Our research approach has also been widened to studies of research training in biology and physics (Lybeck, 1984). The main object of this study is the interplay between the post-graduate student and his supervisor and their interaction with the body of knowledge actualized by the student's scientific problems in the work with the thesis.

Concluding remarks

I have given several criteria of our knowledge production in Math and Science Education. This knowledge production is based on students' conceptions but is also compatible with the knowledge and knowledge production in the individual disciplines. What we today describe as a thought form or a conception of a phenomenon, a principle or a concept was once regarded as forms of knowledge in the respective disciplines.

There is a tendency to emphasize how the students comprehend the world around them as a basis of teaching and learning. I agree with this emphasis, but it is not enough. The descriptions obtained of students' conceptions should, in my view, satisfy other criteria than those related to concepts such as validity and reliability in the field of educational psychological research. I have stressed strongly the criteria of relevance related to several aspects in our subject didactic knowledge production.

Persons who are both familiar with the disciplines and teach the subject have participated in our research. An example of this is the study involving chemistry teachers as subjects and as members of the research team (Lybeck, Strömdahl and Tullberg, 1985) which was presented at this conference. The procedures we have worked out may be of interest in Research and Development Work and in-service training as well as in local development works within the school system.

Notes

1. INOM is short for the Swedish name, and can be translated as 'Learning and Conceptions of the World Around Us'.

2. BMN i short for the Swedish name, and can be translated as 'Concept Formation in Mathematics and the Natural Sciences'. The BMN project was carried out during the fiscal years 1975-79. It was succeeded by the FMN project (The Concept of Function in Mathematics and the Natural Sciences - the integrated upper secondary school), fiscal years 1979-82. This paper has been written within the TENAB-GY project (The Theme project on Natural Science Concept Formation in Child and Adult Education - the integrated upper secondary school), fiscal years 1982-87. The three projects were and is sponsored by the National Swedish Board of Education.

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STUDENTS' CONCEPTIONS OF AMOUNT OF SUBSTANCE AND ITS SI UNIT 1 MOL - A SUBJECT DIDACTIC STUDY

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This study consists of (1) an empirical study of upper integrated secondary school students' - studying natural science line (N line) - conceptions of the quantity *amount of substance* and its SI unit 1 mol (Swedish standard SIS 016132, 1976, SIS 016174, 1976, SIS handbook 103, 1972), (2) a schematic overview of how the quantity is dealt with in Swedish educational materials in chemistry at the upper integrated secondary school level, (3) a description of SI, and (4) a study of the historical development of the "mole concept" and some related quantities. Finally, as a result of our didactic study, we have elaborated (5) an alternative presentation of the quantity *amount of substance*. This presentation is different from the comparable presentations which are to be found in current textbooks and chemistry didactic and educational literature. Our presentation is a conceptually more clear-cut and simplified explanation of the quantity *amount of substance*, and relates *amount of substance* to other relevant quantities in chemistry and physics. This is achieved with the simple arithmetic, algebra and functional theory which are taught in mathematics at the upper secondary school level and during the first year at that level.

Two science didactic interests contributed to the realization of this research task at the Department of Education at the University of Gothenburg. One of these interests concerned a relevance problem that arises in practice. The amount of substance with the base unit 1 mol is a very central part of the chemistry course. Teachers need to know the students' thought structures in connection with this quantity and related quantities. It is possible that the students would profit more from teaching based on their own *thought forms*.

The second interest was prompted by science didactic reasons. We had previously chosen *strategic problems* in the teaching of physics and mathematics with the intention of developing science didactic research in the natural sciences and matematics, i. e. by means of studies of students' *conceptions of* proportionality and density (Lybeck, 1981a). Nearly 100 years ago, the mathematician and mathematics professor Felix Klein urged that the concept function be introduced as an integral concept in mathematics and school mathematics. The quantity amount of substance has a similar role today in chemistry, particularly in physical chemistry. It is, however, a fact that educational materials mostly do not treat amount of substance as an integral quantity.

Amount of substance is a fairly new quantity and many teachers have not come across it in its present meaning in their training and in-service training.

In the light of this and empirical results already arrived at, it was thus a natural strategic choice to carry out a chemistry didactic study of the quantity amount of substance and its SI unit 1 mol with the aim of widening the scope or our research.

Another reason, compatible with the second interest, was that we felt that a study of amount of substance involves such central concepts in chemistry that our results might well be able to help stimulate a chemistry didactic and chemistry teaching method debate which, in turn, might provide reasons for developing chemistry didactic research. This type of research is practically nonexistent in Sweden.

Some chemistry didactic studies of the "mole concept"

Dierks (1981) has made a summary of the knowledge in this field and a bibliography that cover the period from the beginning of the 1950's to 1980 and deal with what has been written about the "mole problem" in chemistry didactic, chemistry method and chemistry pedagogical literature in both English and German. Dierks (1981) gives examples of conceptual muddiness in the use of the "mole concept" and has found the following three meanings of the word mole used before 1957:

1. "Mole" is used in the sense of an individual unit of mass. (The words gram-molecule, gram-atom and gram-formula are used synonomously.)
2. "Mole" is used in the sense of portion of substance.
3. "Mole" is used in the sense of number (Avogadro's number). (p. 149-150)

Teaching can become very difficult if one does not distinguish between the concrete, i. e. the object or body, and the abstract which expresses a property of the object (see point 2 above). In order to attain conceptual clarity, the chemistry didactic researcher Johann Weninger (1959) has proposed the word *portion of substance* (Stoffportion) as a suitable term to use when referring to the concrete. Stoffportion is accepted in countries where German is spoken (it is said to have been used earlier by many Swedish chemistry teachers (stoffportion or ämnesportion in Swedish)). The teacher can say, for instance, that he has a portion of substance of sulphur which has the properties amount of substance (n), mass (m), volume (V), and number (N).

We have, like Dierks (1981), found that few pedagogical studies have been made of how "mole" is learnt and how it is taught. The majority of the studies concerning learning difficulties and the application of the "mole concept" have been examined by means of stoichiometric calculations carried out by students (Johnstone, Morrison and Sharp, 1971, Duncan and Johnstone, 1973, Hankinson, Hudson and Sanger, 1977, Lazonby, Morris and Waddington, 1982, 1984). These studies deal almost exlusively with the connection between chemical formulae and statements given in terms of mathematical relationships or algorithms. Shayer (Ingle and Shayer, 1971, Shayer and Adey, 1981) bases his theoretical analysis on Piaget's theories of intellectual development (the stage theory). Gower, Daniels and Lloyd (1977 a,b) base their analyses on Gagne's network. These studies have their starting-point in special learning theories and give examples of difficulties encountered by students when they solve problems. However, the students can use other strategies that are not consistent with this type of learning theory. As in the case of Shayer, Herron (1975) uses Piaget's theories as the starting-point for the studies he reports. He provides us with information on the underlying causes. Cervellati, Montuschi, Perugini, Grimellini-Tomasini and Pecori Balandi (1982) have analysed 13 Italian textbooks in chemistry. With this analysis as a starting-point, they have used multiple choise questions to investigate the frequency of mistakes and misconceptions of the "mole concept" among student who have chosen different study paths. This study is more an evaluation of the teaching than a study of how students comprehend the "mole concept".

One task of our empirical study was based on the work of Novik and Menis (1976). They interviewed a group of 29 pupils about their understanding of the "mole concept". The interviews were carried out after a group of 15-year olds had been taught about quantitative aspects of chemistry in a section called "Mass-Volume Relationships", where, among other things, gases are discussed. In the preliminary studies, a multiple choise test related to the above-mentioned section was given to 150 pupils and an analysis was made of the concepts and skills required to solve typical elementary stoichiometric problems (the analysis was a hierarchic, Gagne type analysis). The interview questions were tested in a pilot study with five pupils. The questions were written on separate cards. Each card was given to the student after the interviewer had read and explained the question. When a pupil showed signs of not having understood a subquestion, it was repeated by the interviewer until he was reasonably "satisfied" that the pupil had understood the question. The pupils' answers were taped for subsequent analysis. Suitable measuring instruments (a common balance and a graduated measuring glass) and a container were available if the pupil wanted to use them. Of particular interest is the fact that the interviewer apparently did not follow up the pupils' answers with additional questions. In their analysis of the pupils' answers, Novik and Menis (1976) looked for misconceptions:

1. "Pupils who chose equal volumes as criterion for equal numbers of particles... probably do so because the text emphasises that equal volumes of gases are a measure of equal numbers of particles."
2. ".. pupils explicititly stated that equal numbers of particles can be measured only in gases".
3. "Some pupils... do not see the molar mass as measuring a fixed number of particles".
4. "It is readly apparent that very few pupils in the sample view the mole as a counting unit".
5. ".. it would seem that mole calculations based on mass measurements obscure the more... abstract meaning of the mole".
6. ".. phonetic similarity between mole, molecule, molecular (weight), molar (mass) is an additional source of difficulty". (p. 721)

THE STUDENTS, INTERVIEW TASK AND INTERVIEW METHOD

We interviewed 30 students studying natural science (N-line) at the upper integrated secondary school level about their *conceptions of* the quantity *amount of substance* and its SI unit 1 mol. The students were distributed as follows:

6 students from the first grade, N line, 16-17 year olds, (grade 10)
12 students from the second grade, N line, 17-18 year olds, (grade 11)
12 students from the third grade, N line, 18-19 year olds, (grade 12)

The interviews were carried out at an upper secondary school with several parallel N line classes. A teacher at the school helped us with the students. He gave the students written information from us. We told them that we wanted to pose some questions about the teaching of chemistry. They would answer the questions in an individual, taped, interview with each student. We emphasized that it was just their answers that were important. They were also told that the answers they gave at the interview would be kept private. The teacher would not be told what had been said in order to avoid any effect on their marks. The students were informed that we would decide by lot who would be interviewed. We asked them not to say anything to their schoolmates until all the interviews had been completed, after which they would be released from their promise not to talk. The students were reminded of their promise during the interviews. As far as we could see, they behaved very responsibly.

The students in the different grades were given a number, chosen according to the order in which their names were listed in the school catalogue. Slips of paper with these numbers written on them were placed in a box, and a person independent of us drew the lots, so that the desired distribution of students was achieved. An exception was made, however, in the case of the school's best student as the teacher felt that we ought to interview him (a student in the third grade).

The interviews, which contained more tasks than we shall present here, did not have a time limit. The students themselves were allowed to decide whether they were satisfied with their answers and were permitted to return to questions asked of them earlier. The interviewer told each student that it was just his/her way of thinking about the task that interested us.

The tasks were designed in such a way that the students would be forced to use qualitative reasoning in order to arrive at a solution. We designed the tasks to permit a large degree of flexibility. Our goal was to reach the students' "deep" thoughts and conceptions of mole and amount of substance. The tasks were designed during pilot studies involving ten students at two other upper secondary schools.

We were primarily interested in the qualitative differences in the students way of comprehension of the quantity in question. This is one reason why the students were selected from all three grades. We knew that the students were having difficulties with the "mole concept" and hoped to be able to shed more light on where the conceptual difficulties lay, if the students had studied chemistry for different space of time.

The interviews were carried out in part at the end of April and completed in June, 1982. Prior to the interviews, the 2nd grade students had sat for the standardized national test in chemistry. The subject area had already been taught in the 1st grade during the autumn term which meant that the youngest students had had a reasonable amount of time to think about the subject content. The 3rd grade students had had the opportunity to improve their knowledge and at the same time they had acquired a perspective on the subject matter.

After a few preliminary questions on the subject of chemistry and the students' interest in natural science and mathematics, the students were given the task which was later to become the object of detailed analysis. Figure 1 shows the test configuration used for the "mole" question. The cylinders were marked Ia, Ib, Ic, ... , IIIc.

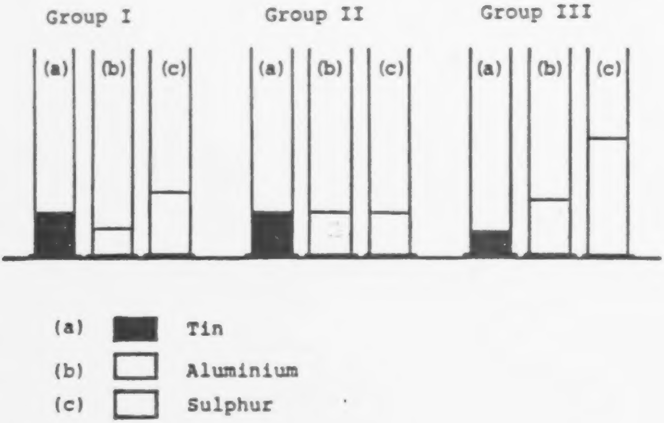

Figure 1: Test configuration for the "mole" question

The student sat directly in front of the test configuration and the interviewer sat to one side. The student being interviewed was first allowed to inspect the plexiglass cylinders and their contents. The students found it stimulating to be able to determine by themselves what elements the three cylinders contained. Before posing the main question the students got the confirmation that the elements were (a) tin,

(b) aluminium and (c) sulphur. The tin and aluminium were in granulate form while the sulphur was in powder form. The students were allowed to lift the cylinders and feel or smell their contents, which was what most of the students did spontaneously. In some cases, they were told that they were allowed to do this. An empty cylinder and a thin plastic mug were placed to one side of the test configuration. The students were supplied with pen and paper. There were no other aids (such as a table of the periodic system or a balance).

The principle of the task is as follows: in group I, the amount of substance is constant (1 mol of each element), in group II, the volume is constant and in group III, the mass is constant.

The task given to the students was formulated as follows:

> "Which group contains 1 mol of each element ?"
> (In most cases, we made the question clearer by adding that there was 1 mol of each element in either group I, or group II or group III.)

The students were asked to explain their choise of group. We asked questions such as "How did you think ?", "How did you reason ?", "How did you arrive at that answer ?", etc. During the interview, we followed up the students' answers in different ways in order to find out how they reasoned. The principle applied at the interview was to allow the student to present her/his own conceptions whenever possible. The interviewer used only such concepts and terms as had been introduced by the students themselves. If the students so wished, they were told the numerical values of the "atomic weights" or molar masses (119, 27, and 32 for tin, aluminium and sulphur respectively). Note that the interviewer did not specify the unit.

If they wished, the students were allowed to asses the weight of the groups by holding them, and when they had reached a conclusion, the interviewer said either yes or no to the experimental outcome, i. e. hers/his yes or no did not apply to the students' own theories. A balance placed to one side of the test configuration would certainly have had a limiting effect on the variation in the students' answers. During the pilot interviews, we discovered that access to a balance was not necessary. If the students had had a balance, the task would have been different and the aim of our study would have been distorted.

When the task had been completed, the question was asked:

"When I say (the word) mole, what do you think of ?"

At the end of the interview, we asked:

"Have you discovered something you hadn't thought of before ?"

These questions led partly to reflections on the task and how it had been solved and partly on chemistry teaching. The students were also given the opportunity to give their own opinions. Some of the students did not want to be told the correct answer. They wanted to spend more time thinking about the task and decide themselves which answer was correct. The students were given the correct answer if they asked for it.

This task was also presented to upper secondary school chemistry teachers and other chemistry teachers at teachers' seminars. These teachers' seminars were also recorded on tape. The teachers felt that the task was relevant and that it had been given at a suitable point in time.

One possible answer might have been: "I cannot answer the question because I don't have a balance and nor do I know what the molar mass is." The question could have been answered by reasoning as follows: We have 1 mol in the group where the mass of each element corresponds with the element's *molar mass*. Since the *molar mass* of each element is different, one can rule out the group were the masses are the same (by lifting the cylinders in order to compare their weights). Since their bulk density is different, it would be a pure coincidence if 1 mol of each element were to have the same volume ($V_m = \frac{M}{\rho}$). Consequently, the group where the volumes appear to be similar should be ruled out. We are then left with group I which contains 1 mol.

We have found that, the visual perception (of volume) often "obscures" the relevant parameter of *mass*. Also the acquired approach consisting of the assumption that number is equal to amount of substance can "obscures" the relevant variable of *mass*.

It is, of course, doubtful whether density aspects should be applied to pulverized substances. Density is given only for well-defined states (the pressure is constant, the temperature is constant, a given crystal structure, etc). Density can help us to calculate approximate masses from estimated volumes. This method does, however, have a number of drawbacks.

The interview method

We have already touched on aspects of the interview method and would now like to comment on this important part of our research methodology. The content-oriented educational research programme in which we are involved has been described by Marton (1981) and the approach to subject education in the natural sciences and mathematics has been described by Lybeck (1981a). Our interview method can be compared with the clinical interview method first used by Jean Piaget in the 1920's. However, Piaget's clinical interview methods have become so influenced by the theories developed within his research paradigm that one cannot agree unreservedly with their conditions. The theories are general and show a clear tendence to distance themselves from the content or phenomenon they are designed to explain. We have given empirical evidence in the case of students' conceptions of proportionality that does not agree with parts of Piaget's theories (Lybeck, 1981a, 1985a,b).

The interview can not be regarded as being separate from the interviewer since she/he is part of the data formation system. The interviewer can be seen as a measuring instrument equipped with a measurement theory. In our approach, expert knowledge of the subject is a prerequisite for carrying out the interview. As a result of her/his studies and knowledge of the subject, the interviewer is able to understand the conceptual relations brought up by the subject. The data formation referred to here consists of obtaining answers from the subjects in order to shed light on their thought processes. We see the *conceptions of* and *thought forms* expressed by the subjects as forming a relation between the subject and the phenomenon, the principle or concept of which, at a certain point in time and in a certain situation, is the object of the subject's attention (Lybeck, 1981a). In subject didactic and subject method research, having taught the subject content dealt with in the interview is naturally an advantage. Familiarity with subject content and the school subject is thus a necessary prerequisite, although not sufficient. This familiarity is part of the interviewer's instrument theory used during the interview. This theory is obviously imperfect and is to some extent a source of error during the gathering of data, but during the time the data is being gathered, processed and analysed, the instrument theory is articulated and improved. The sources of error can be eliminated and criteria drawn up for the data formation process (Lybeck, 1981a,b, 1985a,b). The instrument theory is part of a measurement theory used in the interview method. Other types of error can be taken into account by using this measurement theory. The interviewer can influence the subject to such an extent that the latter's spontaneous thought processes are not articulated or the interviewer may adopt a Socratic attitude and risk taking on the role of teacher.

The interview is flexible and the student's answers are followed up. If this is not possible, the interviewer returns to a previous stage of the dialogue and leads the student back to the phenomenon on which she/he has been asked to express her/himself. The interview starts with a general question and then focuses on more specific questions. The latter questions can serve the purpose of testing hypotheses based on earlier results. In-depth answers should be elicited when ever possible. The subject should be given every opportunity to concentrate on the task and should not be disturbed by irrelevant factors that can break his concentration and interrupt a thought process that has just started.

Our research methodology differs from the research methodology used by Novik and Menis (1976). The mole task used by them in their interviews was in the form of a multiple choice question. This implies among other things that they couldn't follow up the students' answers. Futhermore, our analyses of the students' answers are clearly different from theirs, a fact that can be seen in our results.

Students' view of the interview situation

We shall cite some glimpses from the interviews. When the students are quoted in this way, we have given them code names so that we know which grade they were in. Code names beginning with A represent first grade students of the integrated upper secondary school level (grade 10), code names beginning with B represent second grade students (grade 11), and code names beginning with E represent third grade students (grade 12); all of them studying natural science line (N line). Attention must be paid to the fact that the excerpts from the interviews are translated from Swedish to English.

I:	You were going to say something ?
Bror:	Umm. I thought it was nice, interesting. Especially about moles. It was something I hadn't thought of before. In the way we did it.
I:	What do you mean ?
Bror:	No, you remember! It's like more calculate. My method was to calculate first, but that showed itself to be thinking in circles. Once you start on one idea, it's hard to get off of it, and on to the other. So...
I:	Has this interview given you anything ?
Eva:	It's forced me to think. That's not so usual.
Bodil:	I never wanted to realize that I hadn't understood something before, but I understand that now. You see how hard it is. You must try to start to understand in order to succeed. ... But in any event, it doesn't make any difference how much you study. You can't learn something without understanding it.
I:	Was it a difficult interview ?
Elin:	No, I thought it was fun.
Börje:	I think it was right of you to simply ask which of the group had 1 mol of each element, and nothing else. Had you said more, it would have lead right to the answer..

Britt: But I think it was pretty good because you see about how much one mole can be.

Bruno: It was entirely new. I've never tried in any way to compare... the weights and moles in such a way. What we've always studied has been more abstract, it hasn't been something we saw in front of ourselves. We saw only what was written on paper. I wouldn't say it is wrong, because... in a way, it's easier to work with. It...
Yes, I really think it has given me something... this thing with the test tubes. It's not something that has come up before. It doesn't have to do with the basic course, does it ?

"Mole" - Students' points of view

A few glimpses are cited from the interviews.

I: When I say "mole", what comes to mind ?
Bert: Ugh !

Anders: It's assumed to be very boring to calculate with moles. Very boring.
I: Do you think you could understand fully if you calculated with x as you say, instead of talking about moles ?
Anders: No, I suppose that moles are important for chemistry and that they are needed. Otherwise it wouldn't exist. And we'll be coming to things in the future where it's necessary to have moles and therefore we must have them...

Ann: And then you divide, and multiply, and then... Isn't that what you do ?

Börje: Then I would say that partly... that 1 mol of an element of something decides how many particles. 1 mol of an element stands for a definite number of particles of an element and also that... that mole, if you calculate with number of moles of an element, you get... a painless transition to... which you can easily use to figure out masses and weigh the element if you know the molecular weights.

Axel: A mole represents a number. But at the same time, it's a concept. But it's more a concept than a number. One could say they were equal, but I don't see it that way.
I: How do you use it ?
Axel: I use it when I'm going to figure out how many... how large an amount of an element I have. How many moles and not exactly how many parts it is.
I: Do you think it's difficult to use moles ?
Axel: No, I don't think it's especially difficult. It, it, it's actually. I usually try to set it... to break it down into regular numbers. Or into 1 mol ... and then I don't think about what it stands for in order to make things simpler. It's not that incredibly difficult. It's a matter of understanding it, and not mixing it up with large numbers. I have tried not to do that.

Erik: Yes, otherwise a mole is... You associate it with ... If we picture the term "mole" as a bowl, in this bowl would be Avogadro's constant, and a little Math and a few "equal signs".

The outcome space of the N-line students' conceptions of the quantity amount of substance and its SI unit 1 mol

The interviews were transcribed and checked against the tapes the first time they were processed. The first time the students' answers were read through, we found a large number of statements that seemed to be difficult to categorize.

We did not have an analysis instrument as a starting-point where the answers could be fitted, but we wanted to find one structure which would be able to clearly and simply describe the students' thoughts as they appeared in their answers. Some of the students' statements initially caused us problems: "What does he mean, really ? , How is she thinking here ?", and we read and discussed the interviews innumerable times.

In order to be able to understand each interview, we first constructed a type of tree diagram to enable us to follow the student's lines of thought. We later found that we were more interested in the students' holistic conceptions than the order in which the conceptions were expressed. A structure gradually emerged where the focus was on the amount of substance (n), surrounded by the quantities mass (m), volume (V) and number (N). A simple diagram began to take shape.

At the same time as we were processing the interviews, we also studied the relevant literature. All this took place in many stages, during lengthy discussions and a lot of individual thought over a long period of time (for practical reasons, it was not possible to complete the work in one single period). Looking back now, we feel that the pauses constituted a valuable element of the *qualitative analysis* work. (By this, we mean methodological questions which would be worthwhile discussing in a different context.) We found it extraordinarily fruitful to be confronted with each other's views and criticism during the time we were analysing the interviews.

The outcome space gradually became more detailed as more and more statements by the students were analysed. Here, we wish to emphasize that it is the students' conceptions emerging from their answers that have determined the form of the outcome space. All relations in the outcome space are supported by the students' statements. (A complete presentation of the individual interviews will be published in a technical report by Lybeck, Strömdahl and Tullberg (1985). Thus, it will be possible to scrutinize our empirical results, and indeed, we invite interested parties to be our co-judges).

Figure 2 (see next page) shows the outcome space of the N-line students' conceptions of the quantity amount of substance and its SI unit 1 mol.

In our analyses of the students' answers, we have tried to describe the strategies they used to arrive at a solution. The main features are that the students thematize the task from a continuous perspective (C) or from a discontinuous perspective (D). One group of students pursued a continuity-type line of reasoning with the help of continuous quantities such as mass, volume and density, while another group pursued a discontinuity-type line of reasoning with the help of the quantity number. These lines of reasoning were more or less well-developed, but their emphasis was always either on the continuous (C) or the discontinuous (D). A third group of students coordinated both the continous and the discontinous aspects of the problem in their line of reasoning (C&D). (Chemists do observations at a macroscopic level, but they explain phenomena observed at a microscopic level, i. e. in terms of atoms. The macroscopic observations correspond to a continuous perspective of matter and the microscopic model of explanation corresponds to a discontinuous perspective of matter.)

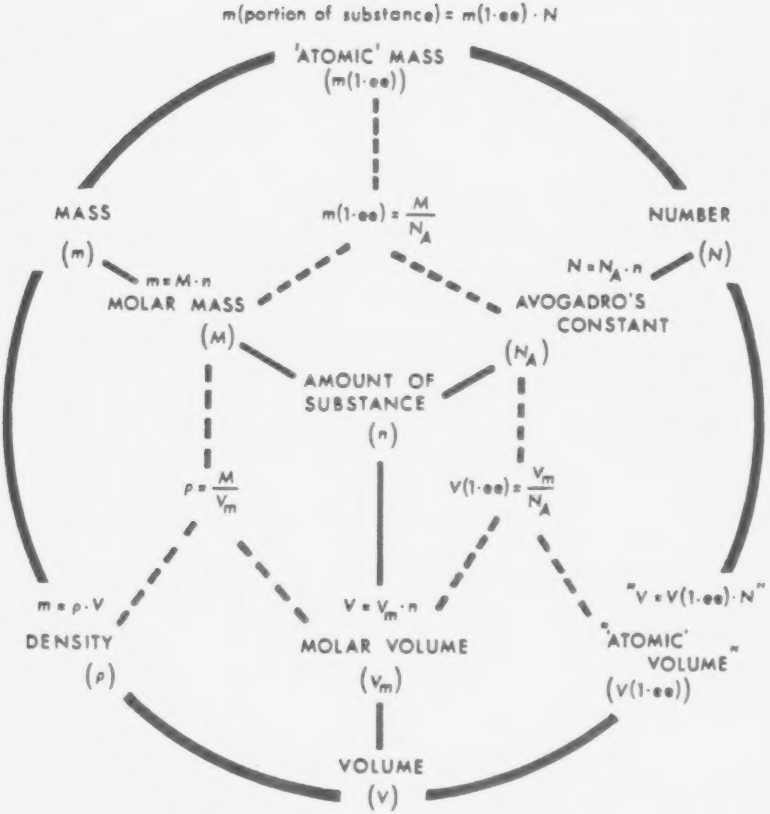
m(portion of substance) = m(1·ee) · N
'ATOMIC' MASS
(m(1·ee))
MASS
(m)
m(1·ee) = M/N_A
NUMBER
(N)
m = M·n
MOLAR MASS
(M)
N = N_A·n
AVOGADRO'S CONSTANT
(N_A)
AMOUNT OF SUBSTANCE
(n)
ρ = M/V_m
V(1·ee) = V_m/N_A
m = ρ·V
V = V_m·n
"V = V(1·ee)·N"
DENSITY
(ρ)
MOLAR VOLUME
(V_m)
"'ATOMIC' VOLUME"
(V(1·ee))
VOLUME
(V)

Figure 2: Outcome space of the natural science line students' (N-line) conceptions of the quantity amount of substance and its SI unit 1 mol. The abbreviation ee, e. g. as in $m(1 \cdot ee)$, is short for elementary entities (atoms etc)

We have classified the students' answers as discontinous (D), continuous (C) and combined (C & D). We are aware that this classification only applies to the students' answers to our questions concerning the task, and on this particular occasion. If the task had been formulated differently, or if the students had been asked to carry out other tasks, it is possible that other areas of the outcome space would have been used by some of them. The point is that we have not classified individuals (as Shayer did with the help of Piaget's theories) but rather the thought content manifested in the students' answers as a relation between the student and the phenomenon she/he has been thinking about.

The students' answers reflected different conceptions of models of the matter. Answers which reflect continuous aspects concerned compaction, grain size, "space between (the grains)", etc. Answers which was a mirror of discontinuous aspects contain thoughts about the atoms' compaction and volume.

Many of the students had problems in combining continuity with discontinuity, i. e. the real, visible worl with the explanation model (the atomic theory).

The outcome space has a well defined and closed form that embraces all the students' answers. It also includes the relations relevant to the posed problem which we later found in the literature we studied. The outcome space is also suitable for the chronological registration of the students' thoughts (numbering the student quotations is all that is necessary). We would like to point out that our outcome space provides a comprehensive description of the students' conceptions of "mole". Futhermore, the outcome space is relevant from a subject theory viewpoint as well as from the point of view of history of science, e. g. the bottom left segment (see Figure 2), that describes Ostwald's original "mole" concept (Ostwald, 1889; see below pp. 60 - 63). The bottom left segment represents the continuous line of reasoning (C) according to Ostwald's view. The bottom right segment represents the discontinuous line of reasoning (D) according to a later development of the "mole concept".

Parts of our outcome space are also found in chemistry didactic literature where they are mostly of an algorithmic character and are intended as instruments and ready-reckoners used to facilitate chemical calculation (Head, 1968, Heup, 1975, Friedman,1976, Slade, 1976, Kolb, 1978, Nilsson, Waern and Wendelöv, 1978, Tullberg and Egneus, 1978). In our outcome space, they are placed in a more comprehensive theoretical context.

The outcome space is a result of our research (Marton, 1981, Lybeck, 1981a, 1985a,b). In addition to the requirements of validity and reliability, the outcome space also satisfies other criteria in subject didactic research (Lybeck, 1981a, 1985a,b) as has been indicated above. What is most important is whether the outcome space is relevant in the chemistry didactic acquisition of knowledge.

In Table 1, we have presented the students' final choice of group as well as their problem solving strategy - either continous (C), discontinuous (D) or combined (C&D).

Summary of arguments given by N-line students regarding their choice of group

The N-line students' final choice of group is shown in Table 1.

Table 1: N-line students' final choice of group

Final choice	Subjects					
Group I	Anders (C)	Arne (C)	Berit (D)	Bertil (C)	Bodil (C)	
	Bosse (C&D)	Bror (C)	Bruno (C)	Börje (C&D)	Egon (C&D)	Emil (C&D)
	Erik (c)	Ernst (C&D)	Eskil (C&D)			
	(Bodil, Bror and Erik chose group III, but changed their choice.)					
Group II	Adam	Alf (C&D)	Axel (C&D)	Björn (C&D)	Britt (C)	Evert (D)
Group III	Ann (C)	Barbro (C&D)	Bengt (C&D)	Bert (D)	Elin (C)	Emma (D)
	Enok (C)	Eva (C)				
No group	Elsa (D) (excluded group II, but could not choose group)					

C = continuity-type line of reasoning

D = discontinuity-type line of reasoning

In Tables 2, 3 and 4, the most important argumentations and reasons for choice of group are presented.

Table 2: ARGUMENTATION FOR CHOICE OF GROUP I

Students: Anders, Arne, Berit, Bertil, Bodil, Bosse, Bror, Bruno, Börje, Egon, Emil, Erik, Ernst, and Eskil (the underlined chose first group III, but changed their choice to group I)

Reasons	Students	Citation	
Mass relationships are correct (Weighing by hand)	Anders Arne Berit Bertil Bodil Bror Bruno (on the request of I (confirms the choise)) Börje Egon Emil Erik Ernst Eskil	Berit:	Wait a minute, mass divided by molar mass, must give the number of mole. If that quotient were constant in one of these sets, then that would mean that the one that has the largest molar mass must have the largest mass.
		Bodil:	(I: What is your conclusion ?) That 1 mol of tin weighs much more than 1 mol of aluminium. And you can compare this when you feel the weights.
		Bror:	(I: But you can give a reason for it anyway.) Yes. That's right. According to this reasoning, the weights seem to be correct, b and c weigh about the same. b is a bit lighter. And a much heavier (in group II).
		Erik:	The first group is also pertinent here. Okay, now it's between group I and group II.
		I:	Why are you eliminating group III ?
		Erik:	Because in that group, the tin and aluminium weigh roughly the same. And tin should weigh three times as much, easily three times as much, almost four times as much. But I have a (see next page)

(cont. on next page)

Table 2 (cont.): ARGUMENTATION FOR CHOICE OF GROUP I

Reasons	Students	Citation
Mass relationships are correct (Weighing by hand)	(See above)	Erik: feeling it's the first group actually. Because the sulfur weighs almost as much as the aluminium, as it should.
		Arne: Mmm. a should be three times heavier than b... roughly. So you must feel them. (I: And they are not ?) The third... no, it's not 3 times heavier.
		Arne: Yes, that... It's more believable that it is Ia, or rather group I.
		Ernst: That's for sure, tin is also the heaviest, there in group II, and as far as I can see even in group I. So one must decide between those two (group I and II).

(cont. on next page)

Table 2 (cont.): ARGUMENTATION FOR CHOICE OF GROUP I

Reasons	Students	Citation
The volume relations are correct Evaluation of density gives volume relationships.	Arne (confirms the choice) Bosse Börje Emil Ernst Eskil	Börje: If we have that... that it contains tin, that it should weigh much more. But then it's a question of density, too. And then one would think that these, where there are equal amounts... (I: In IIa and IIb here?) Yes, IIa and IIb, that there's the same number of moles anyway, because if one thinks that this one is more dense... Because aluminium has a low density, because it's a light metal, because the question is if it... the difference in density is such that it would be able to be that way anyway. But... And then we have that rascal there also (IIc).
		Emil: Exactly, and it can be somewhat difficult to put it (volume) in relation to the mass relationships. (I: Why ?) For example, a lot of air down here. While this sulfur, which is finally broken down, is more compact. But it should be about... Let's see, it was... It is for example improbable that there would be such a large difference in volume.
		I: Do you mean like in the tubes IIIa and IIIb ?
		Emil: Exactly.

(cont. on next page)

Table 2 (cont.): ARGUMENTATION FOR CHOICE OF GROUP I

Reasons	Students	Citation
The volume relations are correct Evaluation of density gives volume relationships	(See above)	Ernst: Then I can see that tin is a finer powder than aluminium. (I: Yes, it is a bit finer.) Then it should take up more space... More space than tin. One kilogram powder should be biggest (volume)... It should come at the end. Yes... Let me think... it should be group I, which is the most logical.
(cont. on next page)		Bosse: (I: Okay, how did you decide that ?) Aluminium comes first in the periodic chart (atomic number), consequently it is lightest (it has the lowest atomic number), even if it doesn't need to be that way according to the density, but let's say that it is. If there is a little (volume) aluminium, then there can be many molecules or atoms in it (the atomic volume for aluminium is less than the atomic volume för tin). (I: Okay, in Ib, you mean.) But the atoms are a bit larger there because it's tin. And then one would think that they would take up a little more space with the same number of mol(ecules)... atoms. (see next page)

Table 2 (cont.): ARGUMENTATION FOR CHOICE OF GROUP I

Reasons	Students	Citation	
(See above)	(See above)	Bosse:	(cont. from page). The same with sulfur. It's... It has a much lower density, because it isn't a metal and consequently there should be quite a lot, and there is.
The volume relations are correct No evaluation of density	Bertil (the volume relations decide the choice, and the mass relations are correct in both group I and II)	Bertil:	The volume is less for the aluminium, in group I than it is in group II. And that seems possible. There is more sulfur in I than in II. So it will even out. So the margins will get larger.
The masses are correct (Strictly speaking the mass of aluminium is correct)	Bruno	Bruno:	27 grams... No, it's probably more correct with this one (group I) when I reflect.

Table 3: ARGUMENTATION FOR CHOICE OF GROUP II

Students: Adam, Alf, Axel, Björn, Britt, and Evert

Reasons	Students	Citation	
The volume relations are correct	Alf Evert	Alf:	Because it should be $6 \cdot 10^{23}$ atoms per dm^3. No, now I am mixing things up.
		Evert:	... yes, it's group II, IIa,b, and IIc.
The number of atoms is constant		I:	And what is your basis for saying that ?
		Evert:	There are equally many, what it is called, 'formula units'... We have 1 mol and as said previously, 1 mol is equal to the number of atoms. Avogadro's constant, if I remember correctly, it's exactly the same number of them (atoms in the tubes).
Constant number of atoms and constant atomic volume causes constant molar volume	Adam	Adam:	They should occupy about the same volume, if they were equally large (constant atomic volume).
		I:	Is that what you're considering now ?
		Adam:	Yes, but these are correct otherwise (group II) because they have... about the same volume.

(cont. on next page)

Table 3 (cont.): ARGUMENTATION FOR CHOICE OF GROUP II

Reasons	Students	Citation	
The volume relations are correct Constant number of atoms causes constant molar volume in spite of varying atomic volume	Björn	Björn:	So, it's the same amount in that case, but then it's a question if the atoms in themselves or the molecules being larger than each other. Sulfur number 15. ... Right, then it's the same number of atoms, isn't it, but... the atoms get larger. ... Well, if the atoms are larger, then they take up more... No, never mind... more space, but it... No, it's probably group II, because there should be as much (volume) in each tube.
		I:	Do all the atoms of all the elements take up the same amount of space ?
		Björn:	Yes... in principle... Yes, it's obvious, they get bigger... but it's ... Everything is so small, the atoms get bigger as you go up in the periodic table.

(cont. on next page)

Table 3 (cont.): ARGUMENTATION FOR CHOICE OF GROUP II

Reasons	Students	Citation	
Mass relationships are correct The volume relations have decided the choice; mass relationships confirm (Weighing by hand)	Adam Britt	Adam:	They weigh the way they should anyway (in group II). This one (IIa) weighs clearly more than that one (IIb). That one (IIc) weighs maybe a little less. It's hard to say.
		Britt:	No. it must be group II ... because it (tin) must also be larger than the other (aluminium), or it (tin) must be heavier than the other (aluminium), otherwise it wouldn't be correct.
The masses (absolute) are correct (Weighing by hand)	Axel	Axel:	And so 1 mol of the element would weigh that much, and it doesn't in that case. That's clear.
		I:	So, it's group III, that you're eliminating... You're feeling IIb...
		Axel:	Yes.
		I:	... and IIc.
		Axel:	IIc and it is pretty impossible to discern how much they weigh... I estimate this weighs more than 119.
		I:	You mean IIa there.
		Axel:	But on the other hand, there's much less in group I here. Because tin weighs more than aluminium and there's a greater quantity of tin here... then I'd eliminate that group too.

Observe that there are reasons for choosing group II other than evaluation of constant atomic volume (compare with Novik and Menis, 1976).

Björn realizes that the atomic volumes increase with increasing atomic number, but "everything is so small". In studies done previous to this study, we interviewed a 16 year old student studying the natural science line (N-line). When he had decided upon group II, he said, "The particles, they are so small, so they must all take up about the same volume". (Notice that the student in this previous study had not studied the gas law as the students of the Israelitic investigation had done.)

Both the student in the previous study and Björn think discontinuously. They support their choices with proper logic, but the non-molar relationship between number and volume causes them problems. There is a gap in their ability at the point, where they are required to go from discontinuity to continuity. It is not impossible that Ernst has also the same understanding of the "number of" - volume relationship (namely that different types of atoms have different volumes, and that the volumes in the required group are the same anyway because the atoms are so small that a small difference in volume does not have any effect). These students believe that the atoms are so small that a volume difference (atomic volume difference) does not make any difference even if the number of atoms becomes very large. The collection of particles creates the continuous characteristics, but how ? This is a question that the student have problems with.

It can be hard to "weigh by hand". For Adam the choice is made by the volume relations and he thinks that even the mass relationships seem to be right ("It's hard to say").

Britt chooses group II because "tin is heavier than aluminium", in other words IIa is heavier than IIb. She never considers "weighing" group I.

Axel thinks it is hard to etimate the masses. "It's pretty impossible to discern how much they weigh", he says. (He is moving towards determining the exact (in fact, absolute) masses.

Table 4: ARGUMENTATION FOR CHOICE OF GROUP III

Students: Ann, Barbro, Bengt, Bert, Elin, Emma, Enok, and Eva (Bodil, Bror, and Erik chose group III, but changed choice to group I. These students thought in continuous terms.)

Reasons	Students	Citation
The volume relations are correct		
Constant number of atoms and variable atomic volume causes variable molar volume	Emma	Emma: 1 mol contains the same number of particles no matter what element you have, but the particles have different sizes (atomic volume is not constant). And that is why I choose group III. There should be different heights in the tubes.
Estimated densities give the volume relationships	Ann Barbro Elin Enok Eva (Bodil) (Bror) (Erik)	Enok: If we think in comparison to the others in the periodic chart then... The answer... umm... should be group III, which is the correct one in that case because sulfur is porous in consistency. So we can eliminate that one for there ought to be most sulfur. Because the others are heavier in themselves if you can use such a weak expression, group III ought to be the right one. ... The weight isn't so important. It's the mole that should be measured.

(cont. next page)

Table 4 (cont.): ARGUMENTATION FOR CHOICE OF GROUP III

Reasons	Students	Citation
The volume relations are correct Estimated densities give the volume relationships	Ann Barbro Elin Enok Eva (Bodil) (Bror) (Erik)	Bengt: I see the difference in... there maybe... Tin... it's little more compact than this one, right ? So I think it's more... Maybe the amount causes it to be 1 mol there and 1 mol there at the same time.
		Elin: No, but like powder (IIIc), it is lighter than that consistency, it looks like it is heavier (IIIa)... It could be lead or something... Only it looks heavier. It's purely visual.
		Eva: ... That the metals have larger densities than sulfur. Then it's possibly between the tin and aluminium. I believe that it is in group III that there is 1 mol of each.
		Ann: I believe you need more sulfur than you need... tin.
		Barbro: Because there is least tin, it weighs most. According to the periodic chart, there is the least amount in that one (IIIa) then aluminium, which is in between sulfur...
		Bodil: I looked at the different levels. Then I know that tin weighs more than aluminium, and in that case lesser amount (volume) of tin is required in order to make 1 mol, than aluminium. (See next page).

(cont. next page)

Table 4 (cont.): ARGUMENTATION FOR CHOICE OF GROUP III

Reasons	Students	Citation	
(See above)	(See above)	Bodil:	(cont.) And quite a large amount (volume) of sulfur is required in order to make 1 mol. ... I know that tin should be heavier than aluminium and sulfur, and then a less amount of tin than aluminium and sulfur would be needed, and that is the case in group III. In group II there is the same amount (constant volume) and in group I, there is more tin (volume).
Mass relationships are correct			
Constant number of atoms and constant atomic mass causes contant mass	Barbro (confirms the choice)	Barbro:	Yeah, they weigh about the same. (I: And they should ?) Yes, they should.
General visual perception	Bengt Bert	Bert:	It is the largest difference between them.
		I:	In group III. I see. Why was it important that there was a difference between them ?
		Bert:	I didn't know. (I: You didn't know?) No, it was like suggested by the question.
		I.	How were you thinking ?
		Bert:	Well, that one looks trickiest. It seems too simple an answer to say group I or group II. Group II seems so super-simple an answer.

(cont. next page)

Table 4 (cont.): ARGUMENTATION FOR CHOICE OF GROUP III

Reasons	Students	Citation	
General visual perception	(See above)	Bengt:	Well... If you say that it is the same (volume) there, then I would eliminate (group II)... first without thinking (intuitively) then I'll eliminate that one because it's not right.

The most weighty argument for the choice of group III is not (as one might expect) conceptions of constant atomic mass. Group III seems to be right because of an intuitively expected picture of how large a volume 1 mol tin, 1 mol aluminium, and 1 mol sulfur should take up.

Many students have a conception that both of the metals should have a larger density (and therefore occupy less volume) than sulfur. (Aluminium, which is a light metal ought to take up less volume than tin.) Many other students use molar mass as a measurement of density. (See even p 43 ,"Molar volume for..).

I: What is it you wanted to look up in the table ?

Enok: I would be able to look up the molar weight... I could find the density, and then I would just be able to calculate away.

Erik: Um, the density is closely related to the molar mass if I'm not mistaken.

The students believe that the molar mass of tin is larger than the molar mass of aluminium whose molar mass is in turn larger than sulfur's. Therefor, the volume relationships ought to be as in group III. When they get to know that the molar mass of aluminium is less than for sulfur, they are surprised:

Arne: The density ? Well, I know that... The molar mass told me that.. I thought actually that aluminium was heavier than sulfur.

Erik: Well, now we're talking about a different situation. I thought that aluminium was a little heavier.

Bodil: (Gets to know the atomic mass values). Mmm. Isn't it more for aluminium ?

Anders never chose group III, but he thought for a moment that there should be least tin in the correct group. He says at the end of the interview:

Anders: I thought incorrectly at the beginning that there should be least tin...
I: Do you know what you were incorrect about ?
Anders: Yes, ummm... I guess I can say that the tin... Because one atom of tin weighs quite a bit more than the other elements, and because 1 mol of one element is the same number of atoms, no matter what it is...
I: Yes ?
Anders: So this one... Eh, then the amount must... The amount does not depend on the weights, or what should I say... Umm, there are the same number of atoms in... And they have different weights, the atoms, because they have different compositions.

And if we take 1 mol of tin, then it has... The atoms are so well... have a larger mass than one tin atom, so it ought to be a greater amount.

I: When you say amount, what do you mean ? Do you mean how high up it goes in the tube ?

Anders: Yes. That's right.

I: So you're considering the volume here ?

Anders: Yes, that's right.

Amount - different meanings

In the interviews, we have many examples of how students use the word amount instead of a more exact word such as volume, number (of), mass, or amount of substance which in scientific context would be the appropriate expressions. Each and everyone of the students can use the word amount and mean many different things, sometimes without being sure what the word means actually. (Compare Lode (1970, p. 81)). It is by no means true that the word amount is only used synonymously with the amount of substance; a result opposite of the views held by chemistry textbook authors in Sweden. (See below pp. 50 - 51 and 77). The following are examples of how the students use the word amount.

Ann: Well, I think that... First about the amount, how much there is in each one.

I: What do you mean by that ?

Ann: What they contain. Let's see, amount. There are different amounts in different tubes here. It's different... (unhearable) always. How many grams they weigh... etc... For 1 mol, yes, I need to know how much it weighs. Yes, the weight, yes gram then, the amount, the height, then we can say decimeter.

Bengt: Maybe the weight causes it to be 1 mol here and 1 mol there at the same time (group III). ... 1 mol is... a certain amount of an element, and there must be at least 1 mol in all the groups, because 1 mol is such a small amount, or rather, because the amounts in the tubes are so much larger than an amount of atoms. 1 mol of atoms is very small. Even if there are many atoms. I would think so. ... I realize I've confused "amount and quantity", and that one should think about what one means.

Anders: Eh, then the amount must... The amount does not depend on the weights, or what should I say...
Umm, there are the same number of atoms in (in 1 mol of a substance)... And they are different compositions. And if we take 1 mol of tin, then it has... The atoms are so well... have a larger mass than one tin atom (he means: aluminium atom), so it ought to be a greater amount.

Björn: 1 mol of each element should have the same amount of atoms, or, uh, molecular units, or units, what should I say...
Right, it should have a larger mass, but the amount (volume), let's see, the amount should be the same (Whispered)...

Atomic mass - molar mass - unclear meanings

There is a degree of unclearness when it involves the students' differentiating between molar mass and atomic mass (atomic weight). We have found this with many students. The explanation is probably that there is *no table of molar masses in the textbooks*. In practice, the periodic chart is used by the students with the atomic weights included as a "molar mass table".

The transition from formular mass to molar mass most likely causes problems because the formulas mass is a *mass*, while molar mass is a *constant of proportionality* ($m = M \cdot n$).

The following are examples of how the students use the above mentioned quantities.

Bodil: Then I would look it up in a Chemistry table.
I: What do you want to know ?
Bodil: The molar mass. The atomic weight

Anders: Yes, in order to find that out. I believe I would like to have had a periodic chart and see what the molar masses are. They are different...
I: Would you find that in a periodic chart ?
Anders: Yes, you can find the molar mass. But it, but wait a minute... what's it called again ? Yeah, the molar mass is the same thing as this here... how many, what's the other name for it ? I can't remember just now. How many units there are, and that's the same as molar mass.
I: Yes, do you mean that if you could look in the periodic chart, then you'd know what the molar mass was ?
Anders: Then I'd know what the molar mass was, yes.

I: How are you going to find out what 1 mol of tin weighs ?
Erik: By looking in the periodic chart.

Emma: I would weigh them and look in the periodic chart. The number of grams per mol is there.

Elin: Yes, one must know the molar mass.
I: What do you mean by molar mass ?
Elin: Well, it's in the periodic chart.

Eskil: You learn a routine, to find out the molar mass, and that is done by looking up the atomic weight in units (u), and changing it into grams (g). The only puzzling thing is what I've actually done. How many... how much does this weigh ?

Elsa: The periodic chart usually helps in many cases with moles and the like.
I: What does it say in the periodic chart ? What kind of data can you use ?
Elsa: I don't know exactly with this, but the molecular weight can be found there.
I: Does it say the molecular weight in the periodic chart, did you say ?
Elsa: Grams per mol perhaps, isn't there... I don't know grams per mol ?
I: Is there any difference between molar mass, grams per mol ?
Elsa: Yes.
I: In what way ?
Elsa: Grams per mol is therefor grams per mol.
I: What's molar mass, then ?
Elsa: That's a good question. I don't know what to say. Something I made up. I don't know.
Is there really such a thing as molar mass ?

I: If you had 1 mol in one of the groups, what would they weigh ? Tin, aluminium, and sulfur.
Elin: It would weigh so many units, u (as 119, 27, and 32).

I: When I say mole do you think of anyting in particular ?
Ernst: Yes, Avogadro's number.
I: I see. What's that ? What do you mean by that ?
Ernst: Yeah, that depends... I know how much it is. It is $6.023 \cdot 10^{23}$ formular units or whatever they're called. And it's pretty good to have, you calculate with the periodic chart, because the atomic weights are the same masses in grams if you have 1 mol of atoms.

Axel: When you see a periodic chart, and read it, perhaps it says... If we say hydrogen 1.008, hydrogen weighs as much in grams and...

Bror: I have... it is therefor 1 mol and then I have one... weighs a certain number of grams... I can figure out 1 mol with Avogadro's constant and the atomic mass.

Emil: ... that there are as many atoms for each mole, as there are as many atomic units for each gram... Um, the number of grams per mol is the same as the number of atomic units per atom, I would say. In other words, the atomic mass in atomic units also gives the molar mass.

I: What about mole, is it that easy ?
Egon: No it's not easy, it is... nothing is easy here... You try... It's just this constant, Avogadro's number, wherever he got that from.
I: Yes, where did he get that from ?

Egon: I don't know. It's probably just practical.

I: Why is it practical ?

Egon: A practical constant to measure the weight with... Yes to measure the weight or... to measure the amount of an element. The element has a certain atomic weight that's measured with universal mass unit u. And when Avogadro's number... If you take that many atoms then you get the same number except in grams, and it... There's a little larger to calculate, a little more practical. But I don't really know why, how this has been decided. It's probably mathematical, I assume.

Molar volume for solid elements and atomic volume - students' points of view

Molar volume for solid elements causes the students problems. The molar volume for solid elements is obtained with the equation $V_m = \frac{M}{\rho}$ (assuming constant pressure, constant temperature, and defined crystal structure). The equation does not appear for solid elements in the textbooks we studied. Many students feel that molar mass is related to density, but they can not express it explicitly. (Compare "Argument for choice of group III, p 33).

Erik: Um... the density is closely related to the molar mass if I'm not misstaken.

Ernst: Are the volumes of one mol aluminium, tin, and sulfur, equally large ? The molar volumes should perhaps be.

Elsa: ... How large a volume one mol has... We haven't talked much about that so that it's a little difficult.

The elements' volume can conventionally be found by using the formula $V(1\ se) = V_m / N_A$ (assuming constant pressure, constant temperature, and defined crystal structure). The students ponder quite a bit over atomic volume.

Elsa: And there isn't anything that says that they (particles) should be equally large in all the elements, or that they should have the same volume. So you can eliminate group II.

Emma: ... but the particles have different sizes. And that's why I'm choosing group III. There ought to be different heights in the tubes.

Adam: They should take up about the same volume in both, because the atoms are the same size.

Berit: So there can't be the same volume in both, because the atoms are not the same size.

Björn: ... Then it's a question whether the atoms in themselves or the molecules are larger than each other.
...
Yes, if the atoms are larger then they take up larger ... No, forget it... more space, but it... no, it's probably group III, because there should be equal amounts.

Bror: But, the atoms are a little larger because it is tin. And then you would think that they would take up a little more space with the same number of molecules... atoms.

Schematic summary of current Swedish textbooks

We have made a comprehensive inventory of how Swedish chemistry textbooks from the beginning of this centuary until the present time have dealt with "mole" parallel with the interview analyses and our study of the relevant international literature. We have, however, not considered it meaningful to include our findings here since they reflect a specific Swedish tradition. We have limited this summary to a schematic table of current textbooks from which it can be seen that Swedish writers adopt different methodic standpoints in their presentation of the quantity amount of substance and its SI unit 1 mol. The schematic summary is presented in Tables 5 and 6.

Table 5: The quantity amount of substance in three dominating Swedish textbooks

	Andersson et al (1983, 4th edition)	Borên et al (1982, 5th edition)
The quantity amount of substance	"*Amount of substance* (*quantity of substance* (ämnesmängd), usually in abbreviated form as *amount* (mängd))." (p 34)	"... amount of substance (or particle quantity (partikelmängd) or only amount (mängd)." (p 13)
What is measured with the quantity?	(Missing)	"The number of atoms (particles) contained in a substance..." (p 13)
Definition of the unit	"The amount of an element containing this number /6.02 · 10^{23}/ is called 1 mol." (p 34)	(Definition given in accordance with SI)
The Avogadro constant	"Quantity $N_A \approx 6.02 \cdot 10^{23}\ \mathrm{mol}^{-1}$..." (p 34)	"$N_A = 6.023 \cdot 10^{23}\ \mathrm{mol}^{-1}$ ($\mathrm{mol}^{-1} = \frac{1}{\mathrm{mol}}$)" (p 14)
The quantity molar mass	"The mass of 1 mol of the substance (type of ion) is called *molar mass* for the substance (type of ion). 1 g/mol (1 g · mol^{-1})." (p 37)	"The mass of 1 mol of a substance called molar mass. ... the unit 1 g/mol (g · mol^{-1})." (p 15)
Relations between amount of substance and mass	"The following relations apparently apply between the mass *m*, molar mass, *M*, and amount of substance, *n*: $m = n \cdot M$ or $n = \frac{m}{M}$" (p 37)	"mass = amount of substance x molar mass $m = n \cdot M$ $n = \frac{m}{M}$ $M = \frac{m}{n}$" (p 15)

Table 5 (cont.):

Hansson et al (1983, 6th edition)
"... *amount of substance* (another name is *quantity of substance* (Ämnesmängd) or sometimes only *amount* (mängd))." (p 27)
".. is a measurement of a number of particles (atoms, molecules or ions)." (p 27)
"... the amount of substance containing N_A formula units constitutes 1 mol of the substance in question." (p 28) Cf: "We have defined the unit 1 mol as being a fixed number of formula units." (p 28) Cf also the expression "1 mol H = N_A hydrogen atoms" (p 28)
"The quantity specifying the number of fomula units per mol is called the *Avogadro constant*. ... Unit... 1/mol. ... mol^{-1}." (p 28) (No quantity symbol is given).
"By means of " $1\ u = \frac{1}{N_A}\ g$" it is also shown that "1 mol H_2O weighs ... 18.02 g". This results in the molar mass as "the mass per mol formula units" and with the unit "g/mol". (p 29)
"... $m = n \cdot M$ The mass is directly proportional to the amount of substance. This relation can also be written as $n = \frac{m}{M}$ " (p 29)

Table 6: The quantity amount of substance in two new Swedish textbooks

	Dahlstrand (1984)	Lindberg, Pilström and Wahlström (1985)
The quantity amount of substance	amount (amount of substance)	"... amount of substance (or abbreviated as amount (mängd)..." (p 66) (The word amount is mostly used).
What is measured with the quantity ?	"... how much substance is involved. Actually, the number of atoms or molecules or formula units." (p 15)	"... is a measurement of the number of particles.." (p 66)
Definition of the unit	"... 1 mol = $6.02\cdot10^{23}$ pieces (stycken)." (p 16)	"One mol is defined as the amount of substance in 12 g ^{12}C." (p 66)
The Avogadro constant	(Missing). (With the definition given above, the conclution must be that there is no room for the Avogadro constant.)	"$6.023 \cdot 10^{23}$ is called the Avogadros constant and has the symbol N_A." (p 66)
The quantity molar mass	"The molar mass is what 1 mol units weighs, usually expressed in grammes. The molar mass has the sort g/mol. ... The molar mass is the mass per mol." (p 104)	"The mass of 1 mol of a substance is called the molar mass of that substance. Molar mass has the unit g/mol (also written as g·mol^{-1}) and has the symbol M." (p 67)
Relation between amount of subastance and mass	"Molar mass M = $= \frac{\text{mass } m}{\text{amount } n}$ Mass m = amount n · molar mass M Amount n = $= \frac{\text{mass } m}{\text{molar mass } M}$ (p 104-105)	(Does not give any general relations. Factor lable method.)

The International System of Units (SI) - basic physical quantities and base units

A discussion of the question of the choice of teaching content in physical chemistry is appropriate here. As early as in compulsory school, pupils are confronted with the base quantities length (l), mass (m) and time (t) with the base SI-units metre (m), kilogramme (kg) and second (s). At the upper compulsory school level and in upper secondary school, students studying physics are also confronted by the quantities electric current (I), thermodynamic temperature (T) and luminous intensity (I_v) with the base units ampère (A), kelvin (K) and candela (cd). These basic quantities have been introduced as a result of decisions made by international organizations, where the corresponding national organisations have been represented, for instance, the Swedish Standard Association (SIS) is a member of the International Organization for Standardization (ISO). The decisions arrived at are of great importance to individual countries.

Decisions are prepared and made in international scientific organizations which have their equivalents in individual countries. Basic quantities, which are independent of each other, and base units are internationally agreed upon, and are introduced parallel with advances in the natural sciences and technology. (See i. e. Siegbahn (1965) and Ohlon (1974)). These quantities with their base units, as well as quantities and units derived from them, become the teaching content taught to students in schools all over the world. The teaching of these concepts is a normative demand made by society. The task of subject didactics and subject method is to solve the problems arising in teaching and learning.

The six physical quantities in the international unit system SI (Système International d'Unités; often tautologically called the SI system) was 1971 supplemented by an independent seventh quantity (number six in order), namely the quantity *amount of substance* (*n*) with the base unit of 1 mol (the name of the unit '1 mol' is mole). The fourteenth conference (1971) held by CGPM (Conférence Général des Poids et Measures) determined the following definition of the base unit mole:

> "The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.
>
> When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles."
> (IUPAC, 1979, SIS 01 61 32, Issue 2, First day of validity 1976-11-15)
> (In the definition of the mole, it is understood that unbound atoms of carbon 12, at rest and in their ground state, are referred to.)

In French, amount of substance is called quantité de matière and in German, it is called Stoffmenge. It is interesting to note that the Swedish name "ämnesmängd" has been used for many years instead of "substansmängd" (the name to-day). The Swedish word "mängd" is the translation of amount, and it has a meaning close to the German word "Menge". A meeting was held between representatives of the Swedish Chemical Society, the Swedish Standard Association and the Swedish Centre of Technical Terminology, due to among other things a mistranslation of the French matière. The following recommendation was agreed on:

> "The term for quantity with the unit mole is amount of substance (substansmängd). In chemistry, the term "ämnesmängd" is common. The abbreviated form "mängd" (amount; quantity) can be used when there is no danger of misunder-

> standing. When necessary, greater precision can be attained by the use of terms such as electron quantity (elektronmängd), photon quantity, etc. (TNC-Aktuellt 1975:1 and the Journal of the Swedish Chemical Society 1975, No. 4, p. 56).

Presumably, the Swedish term for the quantity amount of substance is a sign that different conceptions of amount of substance exist (Holmström, 1975). The word amount (Swedish: mängd) brings to mind the mathematical term amount (set; Swedish: mängd) and the word quantity (Swedish: mängd, or more seldom kvantitet) brings to mind number. In 1967, the definition of the base unit mole quoted above was proposed by The International Union of Pure and Applied Chemistry (IUPAC, 1967, 1979 (1969, 1973)). Ten years earlier, The International Union of Pure and Applied Physics (IUPAP, 1958) argued in favour of the following definition:

> "1 mole (symbol: mol) is the quantity of substance which contains the same number of molecules (or ions, or atoms, or electrons, as the case may be) as there are atoms in exactly 16 gram of pure oxygen isotope ^{16}O"

On the former occasion, quantity of substance was clearly not considered to be an independent quantity. The most important alternation in the definition of mole is the addition "of a system". Amount of substance is a measurable quality, an abstract quantity, of the concrete phenomenon called a system in the latter definition. In the former definition, the statement "which contains the same number of molecules" clearly cannot refer to the abstract term quantity of substance. This definition is conceptually incomplete.

Both definitions of mole are directions for an experimental comparison between concrete systems, and it is thus necessary to specify the elements of the system (elementary entities). It is in the acual comparison with 0.012 kg ^{12}C that one can obtain an experimental estimate of the number of elementary entities in exactly 0.012 kg ^{12}C. It is this number that is called the Avogadro number which is represented here by N_0. The number N_0 is thus a number and can only be given approximatively with an accuracy determined by the measurement procedure. (The value of the Avogadro constant, the quantity symbol N_A in SI, is specified as a physical constant in SI (IUPAC, 1979). Since the physical constants were brought into line in 1973, CODATA (Committee on Data for Science and Technology) has recommended the value $N_A \approx$ 6.022045 (31) $\times 10^{23}$ mol^{-1} (uncertainties: 5.1 ppm). The numerical value for the quantity N_A is N_0. A new adjustment was planned for completion in 1984. Fresh experiments have resulted in better values being obtained for some of the constants, e. g. for $N_A \approx 6.0220978(63) \times 10^{23}$ mol^{-1} (1.04 ppm). Here, it should be noted that the new values found for constants should not be combined with the values found for constants in an older version (see Review of Modern Physics, 56(2), Part II, April, 1984)).

Brief historical presentation of the "mole concept"

There are historical reasons for the introduction of the quantity amount of substance and its SI unit 1 mol. We have not been able to find any studies of the history, sociology or theory of science that give a holistic view of the conceptual development of the mentioned quantity. However, we would like to present a number of circumstances that are relevant to our study, although we realize that reasons we are not aware of may also have influenced this conceptual development.

There are primarily three conceptual lines of development which, at different times, have interacted in different ways and which have finally been integrated as a result of the introduction of the quantity amount of substance and its SI unit 1 mol. The first line of development concerns the introduction of the concept of atomic weight and new methods of determining atomic weights (atomic masses) with increasing accuracy. The second line of development concerns the introduction of the term of "mole" in chemistry. In recent decades, this term has been called "the mole concept" (Kieffer, 1962). The third line of development concerns the place of quantity calculus in the acquisition of scientific and technological knowledge.

Introduction of the concept of atomic weight (atomic mass)

Mattauch (1958a), Wichers (1959), Ölander (1961), IUPAC (1961), and Adell and Andersson (1964) have described the historical development of the concept of atomic weight beginning with the Englishman John Dalton. It is interesting to note that the systematic, quantitative study of chemical processes began with the Stahlians (they used the concept of phlogiston) Bergman, Wenzel and Richter (Berzelius, 1818, Walden, 1931). According to Walden (1931, p. 84), Wenzel was the first person to make atomic or equivalent weight measurements for the divalent cations copper, iron and zinc (copper is percipitated with iron or zinc). At the beginning of the 19th century, the stoichiometric laws governing "equivalent proportions" and "constant proportions" were confirmed by several chemists, e.g. Proust. These laws, as well as the law of "multiple proportions" discovered by Dalton /1803/ and proved definitively by Berzelius (from 1807), were given an elegant explanation in the atomic hypothesis. Dalton postulated that matter is discontinuous. The different elements consist of atoms which, for each element, are characterized by weight (mass) and size. The heavy emphasis on mass distinguished his theory from earlier atomic theories. Dalton was able to utilize a large body of knowledge about quantitative relations found by using scales to make measurements of mass. In 1803, Dalton was first to attribute the elements' atoms a certain definite and immutable weight (mass). Futhermore, these atoms were of the same type. Dalton chose to specify the weight of one hydrogen atom as 1 (H=1), and he published the first atomic weight table in 1808 (Dalton, 1808).

J. J. Berzelius carried out far better atomic weight measurements than Dalton and published atomic weight tables in 1818 and 1827. Berzelius considered oxygen to be the most important of all elements since it can combine with almost all the other elements. He specified the atomic weight of oxygen as 100 (O=100) and in this way he wanted to establish the scale of atomic weights.

In the 1850's and 1860's, the Belgian J. S. Stas carried out extremely accurate atomic weight measurements. He used the atomic weight of oxygen as the basis for his work (O=16), but he considered this to be equivalent to specifying the atomic weight of hydrogen as 1 (H=1) (Adell and Andersson, 1964). The ratio between the atomic weights of oxygen and hydrogen was to play an important role. At the beginning of the 20th century, the ratio was found to be 15.88 : 1 or 16 : 1.008.

The German Wilhelm Ostwald proposed in 1885 that the atomic weight of oxygen be specified as 16 (O=16) which would make it possible to combine the advantages of the two atomic weight scales. At that time, the majority of atomic weights were related with greater accuracy to oxygen than to hydrogen. The atomic weight scale based on oxygen would also provide approximately the same numerical values of the atomic weights as in the case of the hydrogen scale (H=1) where the atomic weights tended to be suitable numbers (Wiffen, 1960). At the beginning of the 20th century, there were tables of atomic weights based on either hydrogen (H=1) or oxygen (O=16). At the end of the 19th century, the chairman of Deutsche Chemische Gesellschaft in Berlin took the initiative in the question of an international scale of atomic weights. A committee was appointed with H. Landolt as its chairman and W. Ostwald and K. Seubert as members. One of the first steps towards international collaboration in the field of theoretical chemistry was taken as a result of the above-mentioned persons utilizing their position in the international scientific community. Chemists voted several times and it was many years before it was decided internationally to use the atomic weight of oxygen, which was specified as 16 (O=16), as the basis of the atomic weight scale.

Soddy introduced the isotope concept in 1910 and just before World War I, J. J. Thomson discovered that the elements could be made up of atoms with different weights (neon had two isotopes with mass number of 20 and 22). F. W. Aston continued Thomson's work and in about 1920 he designed the first mass spectrograph. Aston showed that the natural elements often consist of combinations of two or more isotopes. However, he specified O=16 as the basis of the atomic weight scale. But in 1929, Giauque and Johnstone discovered that oxygen had more than one isotope. In 1935, Urey and Greif constructed a theory that showed that oxygen in different compounds or phases which are in a state of equilibrium does not have the same average atomic weight. That same year, Dole carried out experiments that showed the same results. Thus, the oxygen in the air had an atomic weight of 16.00008 if the oxygen in Lake Michigan was specified as being exactly $^{16}O = 16$. Scientists working with masspectrographs continued with the system $^{16}O=16$ while the chemists used the natural oxygen mixture, where O=16, as the basis of the atomic weight scale. The chemists stuck to this basis in spite of the fact that it proved to be poorly defined. However, this was not a problem in practice since none of the chemical atomic weights had been specified sufficiently accurately to make the uncertainty of the basis significant. This, then, is how the physical and chemical atomic weight scales originated.

The two atomic weight scales meant that double values were obtained for the Avogadro number (N_0) as well as for constants such as the gas constant and Faraday's constant (electrical charge). From about 1940, the proportions ^{17}O and ^{18}O which occur naturally are known, and since that time, scientists and researchers have referred to a defined isotope combination and not to variable, natural oxygen. The conversion factor between the atomic weight scales is 1.000275.

The physical scale also proved to be far from ideal. Different types of carbon and hydrocarbon ions form easily in mass spectrographs. These ions also form easily measurable duplicates with other ions. Thus, in reality, carbon 12 (^{12}C) became a secondary standard. Furthermore, the proportion $^{12}C : {}^{16}O$ was not as reliable as the ratio of a number of other atoms to ^{12}C (Ölander, 1961). There are a large number of reasons in favour of having ^{12}C as the standard. These have been presented in great detail by Mattauch (1958a).

From a chemical point of view, the basis chosen should be a stable nuclide and in the middle of the 1950's, fluorine (exactly ^{19}F) was proposed (see Mattauch, 1958a,b). At a meeting of the Atomic Weight Commission in 1957, two physical chemists (Ölander and Emeleus) were questioned on matters concerning the atomic weight scales. They rejected the physical but found the fluorine scale acceptable (Ölander, 1961).

For the sake of completeness, it should be pointed out that the two atomic weight scales are relative scales and that there was also an absolute scale based on the quantity mass with the unit 1 g.

The discussion regarding the atomic weight scales at the time of the meeting in 1957 was about (1) how the definition of the chemical scale could best be made more precise, (2) whether the physical and chemical scales should be integrated or not, and (3) whether the definition of the physical scale could be improved (Kohman, Mattauch and Wapstra, 1958a,b). Prior to the meeting, the North American physicist A. O. Nier had proposed that ^{12}C consist of exactly twelve "atomic mass units", but this proposal was not brought up by Mattauch at the meeting. Shortly afterwards, the Swede A. Ölander also proposed, independently of Nier, ^{12}C since this nuclide was just as acceptable as ^{19}F. The atomic weights would be reduced by 43 parts per million. Ölander also proposed $^{18}O = 18$, since this nuclide was 17.9999 according to the 1957 scale (Mattauch, 1958a, Kohman, Mattauch and Wapstra, 1958a,b, 1959, Ölander, 1961). Between 1959 and 1961, IUPAP and IUPAC adopted *one* atomic weight scale based on $^{12}C=12$. The Avogadro number was reduced from $N_0(O=16) \approx 6.02322 \times 10^{23}$ to $N_0(^{12}C) \approx (6.02296 \pm 0.00017)\times 10^{23}$ (Whiffen, 1960). At the Atomic Weight Commission's meeting in 1969, a comprehensive "cleaning operation" was carried out and in particular, a large amount of work was put into specifying the uncertainties of the atomic weights (Ölander, 1969). It was recommended that the tables of atomic weights be supplied with seven footnotes giving information on the accuracy and the reasons for the degree of accuracy.

The designation atomic weight has been critized at different times. Many people have seen atomic weight as a mass with the units 1 g (1 kg) or 1 u (unit), but in a historical perspective the atomic weights are given without a unit, i. e. in the form of a dimensionless quantity. The first meaning corresponds to the quantity atomic mass while the second corresponds to the quantity relative atomic mass. Their quantity symbols are m_a and A_r respectively in SI.

At the request of Swedish chemistry teachers, a member of IUPAC's nomenclature committee presented a proposal at IUPAC's conference in the summer of 1963 that atomic weight be given the unit 1 d (dalton). The proposal was rejected by the committee since atomic weight should be a dimensionless quantity. Presumably, the reason was that the committee did not want to have two mass units (gramme and dalton) between which the relation would be dependent on the experimental value of the Avogadro number (N_0). Swedish chemistry teachers recommended and described methodic dispositions of chemistry tuition with the unit 1 d (Adell and Andersson, 1964). In an appendix to their article, they pointed out that an international proposal had recommended that the unit be designated "unified mass unit (u)". At symposiums in physics and chemistry arranged by the Swedish Board of Education in the summer of 1964, it was decided to advocate the introduction of the unit "u" in the nine-year compulsory school and upper secondary school. It was also decided that the National Board of Education would be requested to recommend the use of the unit "u" in the syllabus. Pauling and Pauling (1975, p 51) say:"It is customary for chemists to use an atomic mass unit or dalton (d)...". It should be mentioned that in his detailed conceptual analyses, Stille (1955) uses the unit "1 Dalton" for atomic weight in the chemical atomic weight scale. In West Germany, the unit "1 Berz. = 1.66×10^{-24}g is also used (se Lange, 1953a).

Introduction of the "mole concept"

Burger (1983) has studied much of the pioneering work done in chemistry and physics in the 19th and 20th centuries with respect to the quantity number and related concepts such as gram-molecule or mole. An attempt to explain Gay-Lussac's law from 1808 was presented by Avogadro (1811). He assumed that equal volumes of all gases (elements, chemical compounds and different combinations of these) at the same pressure and temperature contain an equal number of molecules (molécules intégrantes). Avogadro's hypothesis resulted in a new gas theory which was difficult to accept at that time due to the conception of gases then prevailing. Ampère (1814) was also thinking along the same lines as Avogadro. It was the work of Cannizzaro (1858), after an accumulation of experimental data that could not be explained by Dalton's original atomic theory, that resulted in the general acceptance of Avogadro's and Ampère's hypotheses.

In the middle of the 19th century, Clausius and Maxwell developed the kinetic theory for gases and the theory of heat. Stimulated by this work, Loschmidt (1865) made a first attempt to determine the size of the "air molecule", and thus, an estimate of the numbers of molecules in 1 cm^3 of air at 0°C and 760 mm Hg. This number is sometimes called the Loschmidt number (N_L). (This symbol was later assigned a different meaning.)

Walter Nernst appears to have introduced "Gramm-Molekül" and Wilhelm Ostwald "Mol" into physical chemistry (Burger, 1983). In 1889, Ostwald used the term "Mol." which he later replaced with "Mol". These abbreviations of the words "Molekül" or "Molekel". "Gramm-Molekül" (or "Gramm-Atom") and "Mol" as used by the physicist Planck at the beginning of the 20th century described something concrete with mass. Ostwald's conception of the continuity of mole denoted a chemical mass quantity (Stille, 1955) where each type of molecule had its own individual "amount of mass". Mole may have denoted a definite "portion of substance", a term introduced by Weninger (1959) as mentioned above to denote a concrete amount of materia.

The stoichiometric laws were proved to be definitive at the turn of this century and Ostwald was able to authoratively write that the masses transformed in chemical reactions were not

> "... gewöhnliches Gewichtmass, sondern durch solche Gewichte messen, welche im Verhältnis der chemischen Äquivalenz in Bezug auf die fragliche Reaktion stehen. Meist kan man als Einheiten die in Grammen ausgedrückten Molekulargewichte benutzen, die früher schon mit dem abgekürzten Namen Mol bezeichneten Grössen. So wird in Zukunft stets gerechnet werden: die Menge 0,5 Mol Chlorwasserstoff z. B. ist gleich 18,23 g," (Ostwald, 1911, p. 212)

The term mole was quickly linked to the gas laws and Avogadro's hypothesis:

> "Eine solche Menge irgendeines Gases, welche das Volym von 22412 ccm im Normalzustand einnimt nennt man ein Mol." (Ostwald, 1917, p. 44)

Nernst wrote:

> "Mit Hülfe von Avogadro's Regel lassen sich die Gasgesetze in folgender Form zusammenfassen. Ziehen wir von den verschiedenen Gasen eine g-Molekel in Betracht (d. h. das Molekulargewicht, ausgedrückt in g, also z. B. 2 g H_2,

> 32 g O_2, 18 g H_2O u.s.w.), so besteht, wie für jede Gasmenge zwischen p, v und der von $-273,1^\circ$ an gezählten Temperatur T die einfache Beziehung:
>
> $$p\,v = \frac{p_o\,v_o}{273,1}\,T = R\,T\,;$$
>
> hierin hängt aber der Faktor R nur von den gewählten Masseinheiten ab, er ist unabhängig von der chemischen Zusammensetzung des betreffenden Gases."
> (Nernst, 1893, p. 32)

> "Nach Messung über die Dichte der verschiedensten Gase würde der Druck, welchen eine g-Molekel oder ein Mol (bold type), wie man neuerdings passend abgekürzend sagt, eines Gases bei 0° auf die Wände des Gefässes ausübt, 22,412 Atmosphären betragen, d. h. einem Drucke von 22,412 x 760 mm Quecksilber von 0°, gemessen auf dem Meeresniveau an Orten mittler Breite, entsprechen, wenn der dem Gas dargebotene Raum einen Liter beträgt." (Nernst, 1921, p. 49)

The connection between mole and a number of particles (the Avogadro number, the Loschmidt number, L (N_L)) was initially most obvious in physics. It was not until the 1930's that the Avogadro number was included in the definition of mole in the educational litterature used to teach chemistry (Hawthorne, 1973, p. 284). However, the Avogadro number was first more widely used in the explanation of the electrolysis phenomenon. In the 1950's, linking mole and the Avogadro number became increasingly common in the literature published in English. In Sweden, this did not become common practice until the beginning of the 1960's.

The German word for amount of substance is Stoffmenge. It was used in the following way by Ostwald:

> "Als Kapazitätgrösse kennzeichnet sich Stoffmenge, welcher die chemische Energie proportional ist, und deren Betrag keinen Einfluss auf ein gegebenes chemisches Gleichgewicht hat. Man muss diesen Begriff durchaus nicht mit der Masse oder der Gewicht verwechseln; er ist beiden Grössen proportional, aber mit keiner von ihnen identisch." (Ostwald, 1909, p.275, 1917, p. 270)

> "Zwei Stoffmengen sind ausser durch ihren Zahlenwert im allgemeinen noch durch ihre Art verschieden. Eine Folge davon ist, dass man Massen oder Volume unbeschränkt addieren oder zusammensetzen kann, während man chemische Mengen nur dann addieren kann, wenn sie gleicher Art sind. Ausserdem bestehen zwischen den chemischen Kapazitätsgrössen noch die Beziehungen, die durch die chemische Gleichungen auf Grundlage der stöchiometrischen Gesteze ausgedrückt werden können." (Ostwald, 1909, p.276, 1917, pp. 270-271)

It is interesting to compare the first quotation from Ostwald with what Guggenheim said in a recommendation prior to the introduction of the quantity amount of substance into SI:

> "During the past score of years the view has been accepted by a rapidly increasing number of physicists and chemists that there is a third quantity different from mass and weight but proportional to both. This quantity was first named "Stoffmenge" in German and the English translation is "amount of substance." (Guggenheim, 1961, p.87)

Guggenheim (1961) gives several examples of how this new quantity can be measured.

How Ostwald related the term "Stoffmenge" to the "mole concept" is not made explicit in the texts we have had access to. It is of great interest to note that in his introduction, Ostwald

(1909) accepted the atomic hypothesis as a scientific theory based on experimental proof from, among others, J. J. Thomson and J. Perrin. In the case of stoichiometry, Ostwald considered the atomic theory to be instrumental since essentially it was important as a convenient way of illustrating in this area. He considered that it was possible to arrive at an explanation without the help of the atomic theory. Ostwald was clearly in favour of a conception of continuity in this field of chemistry.

Quantity calculus and the introduction of amount of substance

Earlier, the "mole concept" had been used without distinguishing between the quantity and its unit. Dierks (1981) says that the "mole concept" discussion started in West Germany in 1953, but it has its roots in a debate that started before World War II and was continued by Germans during the war. Physicists and researchers in the field of physical chemistry were apparently involved in this debate. Stille (1955) has summarized the detailed analyses made by Pohl (1943), Pohl and Stöckmann 1944, Pohl (1952), Lange (1953a,b, 1954a,b) and Westphal (1954). A common feature of the works mentioned above is that they were in favour of quantity calculus being used in scientific calculation.

According to quantity calculus, a physical quantity is the product of a numerical value (a number) and a unit:

Quantity = Numerical value . Unit (from Maxwell).

The SI's seven independent basic physical quantities are such quantities. All other physical quantities in SI are regarded as being derived from, and have units derived from, the seven independent basic quantities by means of definitions that only apply the mathematical operations of multiplication, division, differentiation and/or integration (IUPAC, 1979). The base units in SI are altered from time to time, as in the case of the definition of the metre in 1983 (the speed of light is defined as c = 299 792 458 m/s and the metre (1 m) is the distance light moves in a vacuum during a period of time of 1/299 792 458 s). The "mole unit" was defined in 1957 with the help of the oxygen isotope ^{16}O. From 1971, the definition with the nuclide ^{12}C, which has been discussed above, applies. Thus, the choice of unit does not affect the quantity as such. As far as we know, the precision balance and the mass spectrometer constitute the most accurate method of determining the ratio between two amounts of substance.

In 1961, the physicists' and chemists' definite agreement on a single atomic mass scale based on the nuclide ^{12}C removed any remaining obstacles to the introduction of a seventh basic physical quantity in SI. Chemists were already applying quantity calculus to other quantities, but the "mole concept" was in a unique position. In 1957, IUPAP had recommended physicists to regard the mole as a unit for "quantity of substance" (with the symbol Q) (de Boer, 1958). This unit was based on the isotope ^{16}O, as mentioned earlier. The quantity and its unit should be regarded as a basic physical quantity and a basic unit. The molar mass was defined as $M = \frac{m}{Q}$ with the CGS unit g/mole, and analogically for the molar volume. The Avogadro constant was defined as the ratio $N_0 = \frac{N}{Q}$ with the unit mole^{-1} (the symbol for the Avogadro constant is now L or N_A). Many people felt, and feel, that the chemists have accepted SI as a result of amount of substance having become a basic physical quantity in SI. The requirements of quantity calculus have resulted in the chemists' "mole concept" becoming more physical as well as precise.

Earlier conceptions of matter and quantification

Our surroundings are populated by bodies or objects made up of different substances, some of which are called elements. We know that man identified different elements in nature thousands of years ago. The properties of the elements were described, and they were used in different ways. Let us give an example from more than 2,000 years ago.

King Hieron had commissioned a goldsmith to make a golden necklace, which was to be used as an offering to one of the gods after some happy event. The king had good reasons to believe that the goldsmith had replaced some of the gold with silver. When the necklace was weighed, its weight was found to be equal to the weight of the pure gold given to the goldsmith by the king. A balance was used to check the weight. Archimedes, who was in the king's service, had constructed a measurement theory for balances (Lybeck, 1981a, p. 72). In spite of the fact that it had been proved to a large degree of accuracy that the weights were identical (there was no concept of mass in those days), the king still suspected that the goldsmith had deceived him. Naturally, the necklace had to be made or pure gold; an offering made of anything less than pure gold was unthinkable and would be taken as an insult by the god. If the necklace was made of pure gold, it could be offered with all the necessary expressions of gratitude and the goldsmith would be set free. If, however, the goldsmith was guilty, he would have put the king in a difficult position and thus damaged the king's good relationship with the god. How could this problem be solved from the king's standpoint and from the point of view of society for which this was an important question ?

We know that Archimedes solved the king's problem, which in physics is called Archimedes' hydrostatic problem. With the help of a balance, Archimedes measured the weight of the necklace, a pure gold object and a pure silver object in both air and water. Using these measurements, Archimedes was able to determine with great accuracy the proportions between the weights of the silver and the gold in the necklace (Lybeck, 1981a, pp. 70-74, 107-108). In pictures illustrating this story, one can see a man wearing a crown and sitting in a bath-tub over-flowing with water. Some physics textbooks show a picture of King Hieron's "crown", which is what causes the water in a full container to overflow. This method of determining the proportions of silver and gold is not correct from the point of view of physics since the degree of accuracy is low. In fact, it gives a faulty picture of what physics is and its purpose. The goldsmith was judged on the basis of the measurements carried out by Archimedes with a balance. This is one of the earliest examples of how science was used in the administration of justice (and perhaps _one_ reason why the story has been handed down through the centuries).

The story shows that a scientific picture of the world in which objects consisted of one or more substances had been developed, more than 2,000 years ago. The scientists of that time knew how to distinguish the substances. The methods used were both scientific and had their origin in handicraft. Using scientific instruments, it was possible to determine certain properties of the different substances. Very early on, the determining of systems of measurement for length, volume and weight became a matter for central government. The earliest traces of weights were found in Egypt and are about 9,000 years old (Ohlon, 1974, p. 9). A balance made about 7,000 years ago was found in a grave in Nagada, Egypt (Ohlon, 1974, p. 9, de Boer, 1975, p. 2). Historical evidence of society's interest in the introduction of systems of measurement are given by Walden (1931), Siegbahn (1965) and de Boer (1975). There is evidence that scientists in earlier times had tried to make the basic quantities dependent on each other. One example that can be traced back to the 18th century is the unit for weight (mass). When the metre was introduced in France at the end of the 18th century, it was proposed that the unit of mass be derived from the unit of length. The mass of 1 dm^3 of destilled water at a temperature (of 3.95°C) for maximum density would constitute the unit of mass. This would be possible to reproduce by applying Archimedes' principle. Two Frenchman made a brass cylinder with the volume of 1 dm^3. This cylinder was immersed in water of maximum density and the reduction in weight was determined by using an accurate balance. An archive kilogramme prototype of platina was manufactured. It is thus no accident that 1 dm^3 of water weighs 1 kg.

The fact that scientists once tried to make the quantities in the systems of measurement dependent on each other is due to the level of scientific knowledge at the time. Advances in scientific knowledge have resulted in the emergence of basic physical quantities that are independent of each other; and their numbers are growing, even if the general desire is to keep the number of basic physical quantities as small as possible. In the SI, the current status of scientific knowledge is both focused on and related to a historical development.

It is perhaps no coincidence that our pupils encounter the SI and its basic physical quantities length, mass and time in their physics lessons as early as in their first year at the upper level of compulsory school and again at the beginning of their first year in upper secondary school. Today, physics teaching emphasizes the concept body or object while chemistry teaching stresses the concept substance.

The story about Archimedes shows that he worked with continuous quantities that express properties of objects. Archimedes' pure gold and silver "portion of substances" had the continuous properties of "weight" (mass), volume and specific weight (relative density).

Long before Archimedes' time, scientists and philosophers had proposed untested assumptions, in the natural science world picture that they had created, that substances consist of small indivisible particles which they called atoms. Thus, at an early stage, the scientific picture of the world contained ontological assumptions about the composition of substances. The mentioned scientists and philosophers entertained and comprehended nature from two diametrically opposed perspectives, namely an continuous (C) and a discontinuous (D). In the empirical study the natural science line students' conceptions of the quantity amount of substance and its SI-unit 1 mol as described by the outcome space (Figure 2, p 19) include the continuous (C) and the discontinuous (D) perspective as well as a combined (C&D) perspective. Empirical studies carried out by Piaget, his colleagues and others using his theoretical framework show that children develop at an early stage a spontaneous way of thinking about atomistic conceptions, e. g. as related to a lump of sugar that is dissolved in water, etc. (Piaget and Inhelder, 1941). These thought processes in children and our adolescents show clear parallels with the development of scientific concepts.

Based on the empirical findings we intend to offer a simplified theoretical presentation of the quantity amount of substance and related quantities in chemistry teaching. This presentation has grown out as a logical necessity due to the empirical results and also due to different methodic standpoints adopted by Swedish textbook writers. Our presentation is an attempt to make chemistry teachers aware of the nature of some misconceptions which can be conveyed to the students. The presentation can be regarded as a basic element of one methodic standpoint, but it is not to be looked upon as a text to be read directly by students.

Simplified theoretical presentation of the quantity amount of substance and related quantities in chemistry teaching

At the level of the scientific picture of the world (world picture), basic ideas must be communicable to the layman. Let us now start from certain assumptions in the world picture that concern partly a continuous (C) perspective and partly a discontinuous (D) perspective as regards the conception of the properties of a *portion of substance*. Table 7 shows a number of quantities within the two perspectives. The aim of the presentation is to integrate these quantities by means of quantitative relations.

Table 7: Quantities within the continuous (C) perspective and the discontinuous (D) perspective respectively

Continuous (C) (Property of portion of substance)		Discontinuous (D) (Property of the specified *elementary entities*, e. g. an atom)	
mass	m	mass	$m(1 \cdot ee)$
volume	V	volume	$V(1 \cdot ee)$
density	ρ		
amount of substance	n	number	N
. . .		(Specifies the number of *elementary entities* that are "countable" in the microworld, e. g. by means of mass spectrometric methods).	

The discontinuous approach means that the *elementary entities* (e e) all have the same mass, namely $m(1\cdot ee)$, which is extremely small. However, the number N of elementary entities of these system can *interact* and form a portion of substance with the mass $m = m(N\cdot ee)$ and the amount of substance n. This conceptual model enables a quantification to be made that can link quantities in the two perspectives together. We then obtain two direct proportionalities:

(1) $m = m(1\cdot ee) \cdot N$

(2) $N = N_A \cdot n$

The relation (1) expresses a linear superposition principle (see Lybeck, 1981a, p. 73). The linear superposition principle quite simply shows that the masses of the elementary entities are added (arithmetic) to the mass of the protion of substance. In the relation (1), $m(1\cdot ee)$ is a proportionality constant. At this point, the proportionality constant in relation (2), N_A, is not specified. It is a general constant. The fact that the direct proportionality (2) applies can be understood if one imagines an equally large portion of substance being attached to the previous portion of substance (portions of the same substances). The new portion of substance's amount of substance is then doubled at the same time as the number of elementary entities is doubled, etc. (This explanation is based on a property of the function proportionality which has been called the functional aspect's B form in our studies of how students comprehend the concept of proportionality (Lybeck, 1981a, 1985b). A B-form means that one quantifies within one variable at a time. The functional aspect's A form means that a quantification is made between variables of different quality, as in the relations (1) and (2).)

If we combine the direct proportionalities (1) and (2), the following relation is obtained:

(3) $m = m(1\cdot\mathrm{ee}) \cdot N_A \cdot n$

For the elementary entities (ee) we can write:

(4) $m(1\cdot\mathrm{ee}) \cdot N_A = N(\mathrm{ee})$

(The symbol in brackets (ee) in the relation (4) follows IUPAC's recommendations to include information.)

The direct proportionality (3) can, with the help of (4) be written as:

(5) $m = N(\mathrm{ee}) \cdot n$

Note that N(ee) is an elementary entity specific proportionality constant since $m(1\cdot\mathrm{ee})$ is included as a factor on the left side of (4).

According to SI, 1 mol is the amount of substance (n = 1 mol) in exactly 0.012 kg ^{12}C which we assume to contain N_0 carbon 12 atoms (elementary entities). The number N_0 must exist according to our conception of the substance's composition. However, we cannot know its value until it has been determined experimentally and even then, only an approximative value of N_0 is obtained. The comparison, which the definition of the unit 1 mol constitutes, means, that the amount of substance 1 mol of any substance contains N_0 elementary entities. This definition leads logically to the following pair of values:

(a) $\begin{cases} n = 1 \text{ mol} \\ N = N_0 \end{cases}$

The pair of values (a) can now be inserted into the proportionality (2) which gives:

(6) $N_0 = N_A \cdot 1\ \mathrm{mol}$

We rewrite the relation (6) as

(7) $N_A = N_0 \cdot \mathrm{mol}^{-1}$

This proportionality constant N_A in (2) (the symbol is international) is a new quantity called the *Avogadro constant*. Its numerical value is N_0 and its unit is 1 mol^{-1}. This is derived from the basic unit mole in accordance with the quantity calculus. The number N_0, which is the logical result of the definition of the basic unit mole, is a *number* and is called the *Avogadro number*. Note that N_0 is *not* included among SI's current quantities.

The relation (7) can be inserted into the relation (4). This gives:

(8) $M(ee) = m(1 \cdot ee) \cdot N_0 \cdot \mathrm{mol}^{-1}$

The proportionality constant M (the international symbol) is a *new* elementary entity specific proportionality constant, as noted above, called *molar mass* which has the unit 1 $\mathrm{kg} \cdot \mathrm{mol}^{-1}$, a unit derived from SI's basic units 1 kg and 1 mol. Chemists usually use the unit 1 $\mathrm{g} \cdot \mathrm{mol}^{-1}$ (a practice from the CGS-system).

The proportionality (5) is well-known in chemistry literature and textbooks where it is mostly written as $m = n \cdot M$, i. e. the proportionality constant M takes the place of x and the amount of substance n takes the place of k in the well-known relation used in mathematics $y = k \cdot x$. From a mathematical point of view, these alterations naturally do not matter in the slightest other than that the form $y = k \cdot x$ is customarily used, where the denotations y, k and x are given certain meaning. The very fact that the proportionalities above are not written out and that the order in (5) is not changed reveals that there is no natural integration between chemistry and mathematics teaching, which is inconsistent with curricula and syllabi. In physics teaching, thought patterns of this type concerning quantities and units are logically developed. We see no reason whatsoever for developing different such patterns of thought in physics and chemistry. In general, one can say that B-form thought patterns are used in chemistry when it comes to using proportionality, while in physics, A-form thought patterns are used (see Lybeck, 1981a). As Goodstein (1983) says:

> "Essentially, there are only two types of mathematical relationships between variables encountered in the introductory courses, proportional relationships and additativ-subtractive ones. The scheme of proportions is one of the grand concepts of mathematics; it is ubiquitious in the introductory course and has the additional merit of integrating with the method of dimensional analysis. Central to this as a unifying theme is the idea of *relationships between variables*; application requires focusing on the relationships between the variables rather than on rote formulas." (Goodstein, 1983, p 665).

It is this aspect recommended by Goodstein, our A form, that forms the basis of this presentation. This aspect is, in turn, based on studies of how students comprehend certain types of subject content and in our view, it is the teacher's job to teach the A and the B form. In this context, it is the A form that is in line with SI's mathematical structure.

Chemistry textbooks mostly define the molar mass M as the mass of 1 mol of a substance with a unit of 1 g per mol. Here, according to our earlier studies (Lybeck, 1981a, 1985a), it is a question of a B form as regards the way in which a proportionality (its isomorphic properties) is comprehended. From the student's standpoint, it is not obvious that it is a question of division when the unit is given as 1 g per mol. Our presentation above explains why the units are given the forms they have as derived units. There is no reason to exclude this explanation in textbooks at the upper secondary school level. Note that the B form definition of molar mass means that molar mass has the dimension of mass, which is not true. Our presentation also explains the difference between the Avogadro constant (N_A) and the Avogadro number (N_0). In some textbooks, N_A represents a number, and in the same textbooks, N_A is assigned the unit 1 mol^{-1} without any explanation being given. A presentation of this type creates unnecessary conceptual confusion (according to SI, N_A represents the Avogadro constant). Textbooks do not include molar mass tables. The students use the periodic system as a molar mass table: "All you have to do is add the unit g." Alternatively, the atomic mass table is used: "All you have to do is to change the unit from u to g". This makes it difficult for the students when they learn the concepts involved. For instance, the number 32.1 represents sulphur in the periodic system, which is where the atomic weight is given (in actual fact, relative atomic mass with the unit 1 and the dimension 1). In textbooks and tables, atomic mass is represented by the unit 1 u.

The unit for atomic mass is defined as follows:

> "1 u = 1/12 of the rest mass of an atom of the the nuclide ^{12}C." (Strictly, $1 \text{ u} = \frac{1}{12} m(1 \cdot {}^{12}C)$) (SIS 01 61 74)

The nuclide ^{12}C thus has the atomic mass 12 u. If we also take into account the definition of the unit 1 mol, then the pair of values (b) obtained especially for the carbon 12 nuclide is:

$$\text{(b)} \quad \begin{cases} n = 1\ \text{mol} \\ m(N_0 \cdot {}^{12}C) = 12\ \text{g} \end{cases}$$

We can now insert the pair of values (b) into the proportionality (5) which gives:

$$\text{(9)} \quad 12\ \text{g} = M({}^{12}C) \cdot 1\ \text{mol}$$

$$M({}^{12}C) = 12\ \text{g} \cdot \text{mol}^{-1}$$

(The way in which (9) is written thus expresses the molar mass of the carbon 12 nuclide.)

In accordance with the definition of the units 1 mol and 1 u:

$$\text{(c)} \quad \begin{cases} m(N_0 \cdot {}^{12}C) = 12\ \text{g} \\ m(1 \cdot {}^{12}C) = 12\ \text{u} \end{cases}$$

We insert (c) into the basic proportionality (1) and obtain with the help of (a):

$$m(N_0 \cdot {}^{12}C) = m(1 \cdot {}^{12}C) \cdot N_0$$

$$12\ \text{g} = 12\ \text{u} \cdot N_0$$

$$1\ \text{g} = 1\ \text{u} \cdot N_0$$

And we finally obtain:

$$\text{(10)} \quad \frac{1\ \text{g}}{1\ \text{u}} = N_0$$

The ratio (10) between the units of mass is the absolute number N_0.

Concluding considerations

In the above presentation of the quantity amount of substance and other related quantities in chemistry teaching, we started with the quantities, not with the definition of mole. The definition of 1 mol is often given such a prominent position in the textbook that it obscures the quantity amount of substance. In SI, quantities are fixed. The definitions of the base units are, however, altered from time to time. Thus, however important the definitions of the base units are, it is the quantities that are important when the students learn the concepts involved.

Our theoretical presentation requires only simple arithmetic and proportionality in accordance with SI's requirements. These mathematical concepts are important elements in the teaching of mathematics at the upper level of compulsory school and later in the first year at upper secondary school. The concept of proportionality is the mathematical instrument used to form new concepts in physics and chemistry (and other subjects), e. g. density (Lybeck, 1981a), speed, molar mass and concentration. Thus, proportionality is an integral mathematical structure in the first year at upper secondary school during the acquisition of concepts in physics and chemistry (and other subjects).

Perfectly satisfactory teaching based on number is possible, as Weninger has shown in a large number of studies (e. g. Weninger, 1980, 1981, 1982, 1983). Weninger wants to exclude completely the quantity amount of substance and its unit mole from his chemistry didactic presentation. This has perhaps not been observed by textbooks writers who make amount of substance synonymous with number. Weninger's didactic presentation would be placed in the outer ring of our outcome space (Figure 2, p. 19). Weninger's in-depth analyses do, in fact, constitute a criteria of relevance and validity of our outcome space. This presentation is based on our outcome space.

In his presentation, Weninger seems to adopt the attitude that amount of substance is a quantity that should be deleted from SI. The problem of the transition between discontinuity and continuity is still present in his presentation and is focused on N_0 (Dierks, Weninger, and Herron, 1985). Weninger introduces the "concept" of "hen".

It should be noted that Weninger does not dicuss the proportionalities from the A-form perspective, as we do here. Our aim, on the other hand, has been to make a presentation based on our results, that is as logical as possible and satisfies SI's requirements. SI's requirements have been followed, e. g. by McGlashan (1979) in his textbook on classical thermodynamics. He quantifies exclusively with continuous quantities (e. g. the gas laws).

Weninger's view that chemical calculations should be based on the number of elementary entities is unassailable from the standpoint of chemistry. However, a normative element in chemistry didactics has emerged, formulated by the scientific community through IUPAP and IUPAC. The "SI system" must be followed in accordance with agreements (e. g. in Sweden: see Aktuellt från Skolöverstyrelsen 1964/65:13, p. 193 /National Swedish Board of Education Newsletter/). This requirement means that the concept amount of substance must be taught. We are aware that two perspectives come into conflict with each other here. One perspective - which has a historical basis - where the "mole concept" is referred to (Kieffer, 1962), and a physical science perspective which is most simply expressed by the equation: Quantity = Numerical value · Unit. The structure based on the formation of physical science will now also apply to the quantity amount of substance in addition to length, mass, time, etc. The physical science approach in chemistry teaching has clearly not found acceptance so far. This was one of the results of our study of Swedish textbooks.

We would also like to point out that Holmström (1970) presented a teaching method which includes the term "ämnesmängd", where our proportionality (2) is given. The substance's "molar mass", however, is given by the ratio $M = \frac{m}{n}$. Porportionalities are recommended in East German chemistry didactic literature in particular (Wenzl, 1969, Arndt, 1973, Schellenberg, 1974, Buschman, 1975, Leitz, 1979) and in West Germany by Merkel (1977, 1978) as we noticed recently; better coordination between chemistry and mathematics teaching is also argued for. We intend to return to a discussion of these papers in another context. In our presentation, we have tried to avoid the ambiguities we found in our study of the relevant literature. Our presentation is supported by the following line of reasoning:

> "The amount of substance is proportional to the number of *specified* elementary entities of that substance. The proportionality factor is the same for all substances; its reciprocal is the Avogadro constant." (IUPAC, 1979, p. 5)

This means that our proportionality (2) has the following form in IUPAC's document:

$$(2') \qquad n = \frac{1}{N_A} \cdot N$$

The relations (2') and (2) are identical, but the way in which they are written can indicate a slight difference in approach. In our presentation, the amount of substance is focused on; it is in the position of the first coordinate in the first pair of values (x, y) and in the functional relation $y = k \cdot x$. The way of thinking revealed by IUPAC's document suggests that it is the number that is focused on; the number signified by the definition of 1 mol.

We know that McGlashan played an important role in the introduction of the quantity amount of substance and that it was McGlashan who prepared the text of the document when IUPAC's decisions and views were presented. The presentation given here may give the reader the impression that we are wholly in favour of using the quantity amount of substance. Like McGlashan (1977), we are of the opinion that if the quantity amount of substance and its SI unit are to be used, then they should be used correctly, i. e. so that they satisfy the requirements of quantity calculus. This is one aspect. The other aspect is that science can manage without the quantity amount of substance since it is not necessary. This has been pointed out by McGlashan (1977) and claimed on other grounds by Weninger (1983). Furthermore, there may well be other acceptable views not discussed here.

Aknowledgment

This study has been carried out within the TENAB-GY-project, Department of Education and Educational Research, University of Gothenburg. The research concerns students' conception of concepts in mathematics and science teaching at the upper compulsory and upper secondary school levels, both in youth and adult education.

The project is supported by the National Swedish Board of Education (NCB) the fiscal years 1982/87. This study was initiated during a course based on results from two research projects, BMN and FMN (fiscal years 1975/79 and 1979/82 respectively). The aim of the course was that the upper secondary teachers should apply our way of working and our results in the class-room. The project leader and scientific leader of the above-mentioned projects, ass. professor Leif Lybeck, has carried out this study together with the chemistry teachers, Helge Strömdahl, M.Sc. and director of studies, and Aina Tullberg, Dr. and senior teacher. They are attached to the TENAB-GY-project on a part time basis. They participated in the above-mentioned course, and we carried out the interviews at an upper secondary school where a third teacher attending the course, is teaching. The teacher was very helpful to us, as well as the students who very willingly contributed to this study.

Chemistry teachers, trainee teachers, senior lecturers in methods, textbook authors, senior lecturers and professors of chemistry have been confronted with our results at various times during the study at seminars and in-service days as well as at interview sessions. In one way or another, they have very constructively and critically contributed with experiences. In fact, they were in some sense members of our research group in the progress of this study. The data gathered during

these events will be analysed as a next step in our research programme.

With regard to information on SI, we have consulted a number of informed persons.

Alexander de Courcy has translated the major part of this paper. The part concerning the students responses (pp. 14 - 16 and pp. 23 - 44) has been translated by two third grade N-line students, Derek Bush and Dag Thuvesen, who are American-Swedish scholarship students.

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FUTUROLOGY AND EDUCATION OF PHYSICS AND CHEMISTRY TEACHERS

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Introduction

The need for the futurological perspective in teacher education is obvious: Schools educate pupils for adult life. which begins after few school years. However. teachers should be able to control this educational process over all of their professional years. This means usually a time span of 30 - 40 years. Today we should educate our trainees to be ready in time for the two thousand and twenties. Those needs are probably even more different from the present ones than the present are from the needs of the immediate post-war society. In any case. the possibilities for accurate predictions are growing smaller and smaller in the rapidly changing society.

Aspects of teacher education affected by the futurological perspective.

Teacher education is affected on all levels by the expectations for the future. First. it is obvious. that in a rapidly developing society it is impossible to rely on pre-service education of teachers only. but in-service education is growing more and more important. In-service education provides for the need of flexibility in the organisation of teacher education. In countries with teacher education on the academic level a lengthening of pre-service education is already disadvantageous - here the quality instead of quantity should be emphasized. In cases where in-service education is well developed. it should be defended against any cutbacks. One of the main goals in teacher education should be a positive attitude to continuous education. Teachers should act also as models of behaviour for their pupils by active participation in programs of continuous education.

The second aspect of teacher education having a new emphasis is the way of analysing teaching and learning. While in the past we relied mainly on the experience of "good" teachers. there is a positive need for the use of more general and reliable research data as the basis of decision-making in teacher education. This calls for the science of science teaching, which term was publicized already in the name of the wellknown book by Shayer & Adey (1981). There are also implications for differentiation to didactics of chemistry, didactics of physics, etc. in several countries. The differentiation can be seen also in the didactical literature, where we have books for didactics of most if not all school subjects. The different subject didactics are also to be fields of active research and the research should be in close connection with teacher education. (See for instance Köhler, 1975).

The complementary roles of a scientist active in didactical research and a school teacher in his/her daily work are presented in the diagrams below. A scientist is working on the basis of data from the classroom and striving for generalisations, models and theories. A teacher wishes to select the most relevant of available theories for resolving current didactical problems in the classroom.

There are several aspects in the new way of thinking needed in the future of all teachers and especially in teacher education. One view is based on the idea of didactically thinking teacher, which has been promoted by Koskenniemi (1978). Another is the general view of teaching and learning as a process. The goals given in the curriculum serve as the reference level in the evaluation. Evaluation in turn provides feedback to the process. This seems to be a fruitful approach in the education of science teachers, probably due to obvious analogies to industrial processes and automata.

We have entered the age of information. Its influence can be seen everywhere in the society, and especially as the flood of new research data in the natural sciences. As noted e.g. by Heikkinen (1984), this means that we are knowing every day smaller and smaller portion of the information, which we should be familiar with at least in our primary field of interest. In the Finnish national epos Kalevala there is a frequently repeated idea, that to be able to gain power over something, one has to know its origin, its birth. This wisdom of ancient poems is most valid even today. In the natural sciences the origin of knowledge is in a scientific experiment. (In schools experiments take the form of either teacher demonstrations or student laboratory work.) Only the knowledge of the origin of information gives us the ability to estimate its accuracy and reliability as well as helps in evaluating its relevance. In the present information age one has to learn also skills of information management: how to store. classify. rearrange. update. and activate information. This happens all the time in one's memory. but the abilities to perform these operations in a computer environment are becoming more and more important.

One of the major differences between the world. where our present students in teacher education live. and that of their future pupils. is due to the microprocessor and its various applications. There has been so much discussion about problems of computer education taking as an example the fact that some pupils know far more about home computers and their programming than their techers. However. this situation is no handicap for teachers ar far as they know specifically. how to use the computer as a tool for solving problems related to teaching of his or her subject.

It is seen that in the future there may be a flood of mass-produced goods and information. but one of the bottlenecks may be the creative problem solving and individual personal attendance. Communication skills are important for teachers. but they should also be able to grow in their pupils the skills needed in team work. human communication. observance to other people (related e.g. to safe working procedures). etc.

In the future. anything that can be made by automata. will be automatised and this will lead to reduction of human involvement. This applies both to mechanical work and algorithmic thinking etc. The most important human contribution may be related to moral and human values - and these should be more and more in foreground in schools. Human value skills include the ability to know one's own skills and abilities. possibilities for action in each situation. as well as ability to set one's individual goals. An industrial executive may see this as a creation of a personal development project for everybody. Every teacher should be prepared to act as an adviser and consultant for each pupil. This is not a task for teachers of humanities only. but it will be important for future chemists and physicists. technicians. etc. to have a sense for responsibility. feeling for justice. and so on.

Practical aspects of teacher education

The above considerations have been largely on a theoretical level. but there are major alterations to the present practice of teacher education. if their implications are fully taken into account in the development of future curricula. We are able to consider here only a few examples.

The general trend in the Nordic countries in school administration from centralism towards increasing responsibility on local level has to be observed also in teacher education. Each trainee should know different teaching methods and be able to study individually essential dimensions of teaching-learning situation. In teaching of physics and chemistry it is fruitful to take these dimensions as 1) Human exchange vs. independence. 2) Connection to the real world. and 3) The method of inference. The fourth dimension would be the personal growth of the pupil.

The trainees should be also able to write a minor thesis based on original data from schools. authentic learning material or equivalent. Thus each teacher would have an idea of the origin of the data as the basis for didactical decision making. The emphasis shall not be in the content of teaching but in the flexibility and creative atmosphere in the classroom. All general ideas are to be imbedded in teaching of different subjects - they cannot be brought to the pupils in isolation.

The school laboratory should maintain its importance in the training of chemistry and physics teachers. All teacher education. including in-service courses. should have access to good school laboratories. computer facilities. electronics workshops and mechanical workshops etc. as well as to active school classes. if possible. In training for teaching in the school laboratory. more emphasis should be given to promoting abilities for supervising student laboratory work than for performing demonstrations. The demonstrations are not only for showing the skills of the teacher. but to let pupils in direct contact with real world and the phenomena.

Communication between schools and the surrounding society should be promoted. Parents form a natural interest group. but local industry should not be forgotten by chemistry and physics teachers. School projects connected to technology and industrial production give also local flavor to the school curriculum. Visitor exchange schemes between schools and industry. administration. etc. should be developed. School could be seen as local knowledge and skill centers. Teacher education should prepare trainees for these features of future professional life. too.

Finally. it has to be emphasized. that international connections in teacher education should be facilitated. Teacher education as well as schooling in general should reach international standards. Departments of teacher education as well as all teachers should have access to new ideas through international networks. This does not mean. that national features of education should be suppressed. On the contrary. each nation has the most to contribute from her own background. from ancient traditions to modern specialized industries. and contributing a fresh flavor to the international culture.

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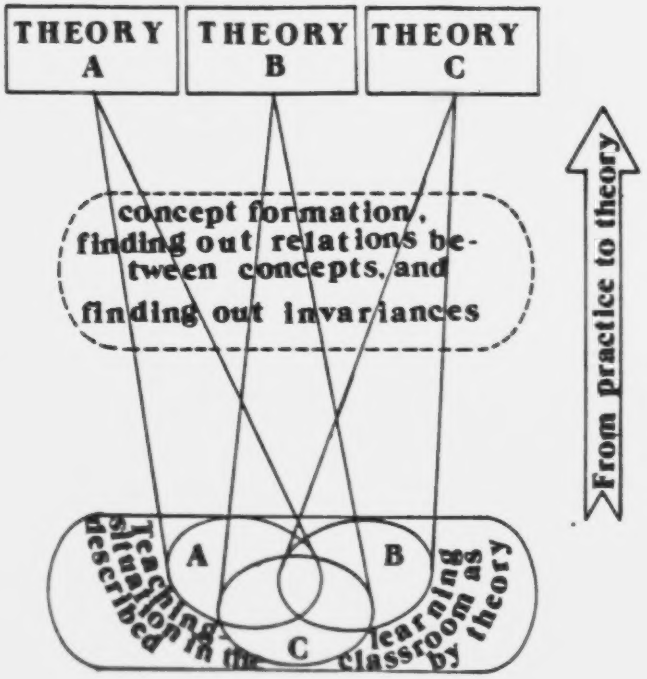
THEORY A
THEORY B
THEORY C
concept formation, finding out relations between concepts, and finding out invariances
From practice to theory
A
B
C
Teaching-learning situation in the classroom as described by theory

FIGURE 1. Different theories and models are constructed on the basis of experience and research data from the classroom. This diagram is visualising the flow of information and other influence from practical to theoretical level.

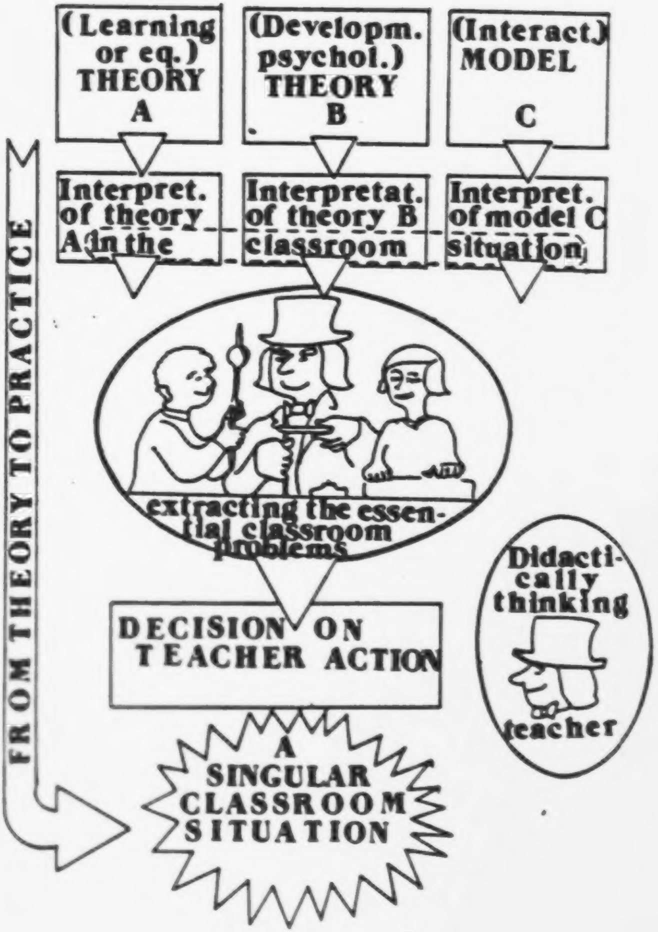
(Learning or eq.) THEORY A
(Developm. psychol.) THEORY B
(Interact.) MODEL C
Interpret. of theory A in the
Interpretat. of theory B classroom
Interpret. of model C situation
FROM THEORY TO PRACTICE
extracting the essential classroom problems
DECISION ON TEACHER ACTION
A SINGULAR CLASSROOM SITUATION
Didactically thinking teacher

FIGURE 2. The didactically thinking teacher extracts the essential problems from the classroon situation and decides on teacher action on the basis of interpretation of various theories or models in the classroom situation. This visualises also the flow of information from theoretical to practical lev

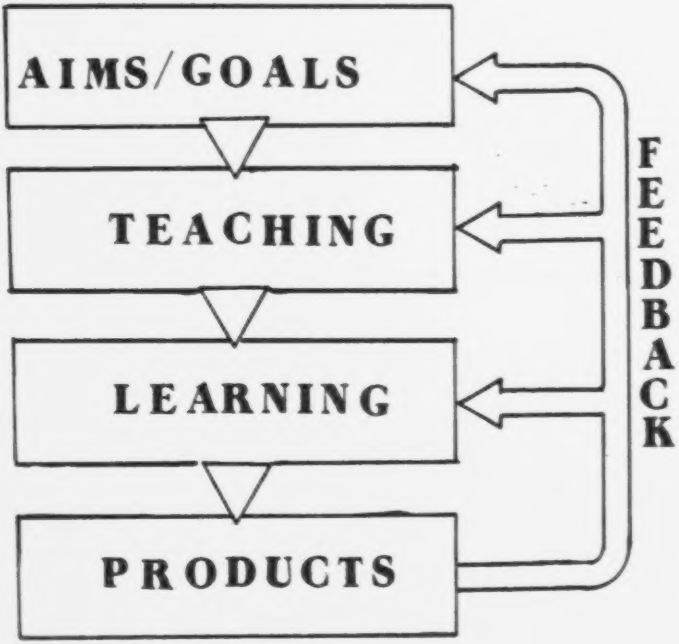
AIMS/GOALS
TEACHING
LEARNING
PRODUCTS
FEEDBACK

FIGURE 3. Teaching and learning as a process. For the feedback one is comparing the learning products with the original aims and goals. This feedback is steering the process on different levels.

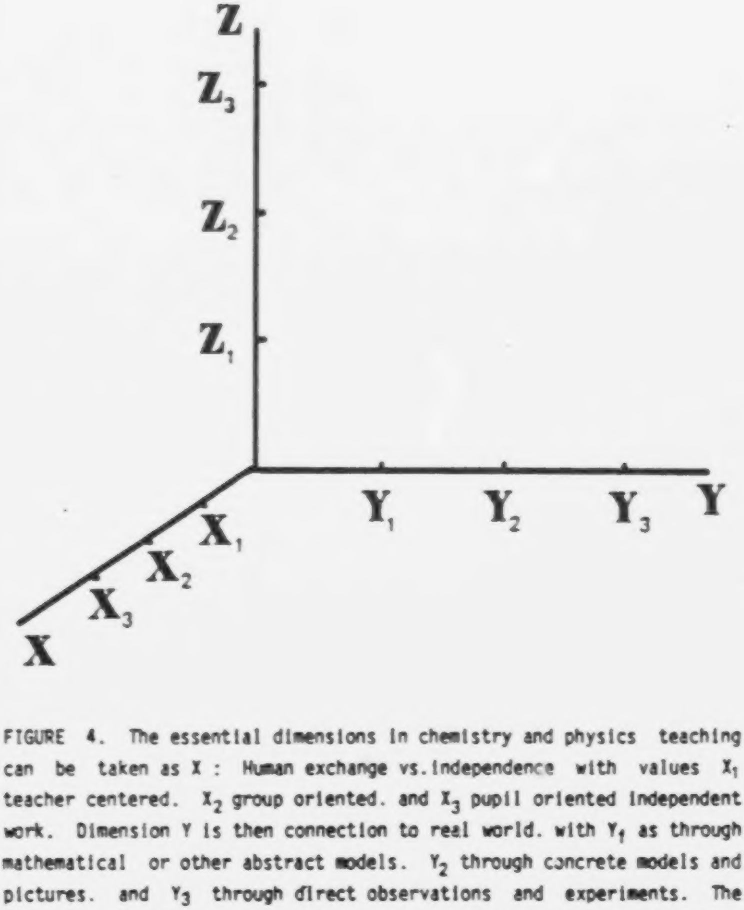

FIGURE 4. The essential dimensions in chemistry and physics teaching can be taken as X : Human exchange vs. independence with values X_1 teacher centered. X_2 group oriented. and X_3 pupil oriented independent work. Dimension Y is then connection to real world. with Y_1 as through mathematical or other abstract models. Y_2 through concrete models and pictures. and Y_3 through direct observations and experiments. The dimension Z. the method of inference gets the values Z_1 deductive reasoning. Z_2 inductive reasoning. and Z_3 reasoning through analogies.

SCIENCE AND SOCIETY IN PERSPECTIVE - A NEW COURSE FOR THE DANISH UPPER SECONDARY SCHOOLS.

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ABSTRACT

A new science course entitled "Science and Society in Perspective" is in the process of being developed. It is planned to be used in physics teaching following the newly revised physics syllabus for Danish upper secondary schools. Below we present the project, its background and its philosophy.

Background

There can be no doubt that the existing physics syllabus guarantees that physics teaching in the Danish upper secondary schools is completely dominated by the presentation of scientific methods and scientific results as these are perceived by the physics community of today. There can also be no doubt that these aspects are bound to be extremely important ingredients in any serious physics education at this age level (16-19 years of age). However, one should be aware that the present rather narrow science centered physics teaching, which has predominated in all western countries since the large curriculum projects of the sixties, seems to have had several unwanted consequences. Many investigations in this country [1,2] as well as abroad reveal that students in general (and girls in particular) consider physics to be the most difficult subject in secondary school. Apart from those who are aiming at a higher education in natural science or engineering, students also complain that physics has little connection with other school subjects (apart from mathematics, of course) and has only little relevance to their lives. Physics to them seems to be a rather static subject, with only a few weak and diffuse links with society. The enormous influence of physics - good and bad - as one of the major driving forces behind the technological and cultural developments of modern society seem to be an almost unknown land for them.

In all western countries these findings have given rise to serious concern among professional physicists, educational scientists and science teachers, and a considerable amount of revision work is now in progress. Perhaps the most significant of these new physics projects is the Dutch PLON-project[3], which is directed towards physics education at secondary as well as early tertiary level and which represents a major effort to provide a radical alternative to traditional physics teaching. Unfortunately, I shall not have time to say more about this interesting project, but I suspect that most of you are already quite familiar with it.

Although not on the same grand scale there has also been interesting developments in Denmark during the last few years: For example, a couple of Danish research projects have provided a substantial amount of evidence on the attitudes of teachers and of secondary school students towards physics. Partly as a result of this evidence, the Physics Teachers Association recently produced a detailed proposal[4] for a new physics syllabus for the Danish upper secondary school, a proposal which has been debated quite a lot since then, and which will be discussed later at this conference. Consequently I shall not go into details but just mention very briefly two of the main changes which would result from this proposal. One is a much heavier emphasis on new technology, e.g. energy technology and information technology, as compared to the present situation. The second is the introduction of a new compulsory physics topic, which in the lack of a better name has been called "The scientific view of the world". This new topic is only vaguely described in the syllabus proposal, although it is said that

> ".... it must put the other physics topics in perspective in order that the students can better appreciate physics as a form of understanding which is dynamical in character and which develops in connection with other forms of understanding".

Although we have taken part in the debate and expressed certain reservations towards the proposed syllabus in its present form, it should be emphasized that we are quite sympathetic to the intentions behind the syllabus. We thus agree, that there is a rather strong case for including more technology and more contact to society in the physics classes. However, one should also be aware of the fact that there is no tradition for teaching such topics in Danish physics courses. A substantial amount of in-service teacher training and a substantial amount of curricular material development will thus have to be organized; otherwise the new physics syllabus will not be succesful, and many teachers and students will soon develop negative feelings towards it. Such activities should thus be given a high priority and stimulated in every possible way.

Already in 1982 at the Institute of Physics, University of Aarhus, we created what has been called The Aarhus School Physics Workshop[5]. From its start it was meant to be a forum for frequent and informal discussions between physics teachers from the University and from the neighbouring upper secondary schools but it has gradually developed into a number of working groups which are concerned with the development of new physics course material. One of these groups selects or develops a large number of simple demonstration experiments for use in physics teaching. Another group has developed a very transparent and cheap microcomputer with the aim of being able to explain to students how microcomputers really compute. A third group works on the socalled Girls and Physics-problem, and finally a fourth group, consisting of 3 university teachers and 4 gymnasium teachers has started a project aimed at producing a series of books on "Science and Society in Perspective". The intention is that the books should be of use in physics teaching based on the proposed physics syllabus for the Danish upper secondary schools. And it is the philosophy underlying this last project to which we shall now turn.

Philosophy

Very briefly the aim of the project is to create a series of books which can give the students a feeling for the evolution of science, an understanding of the role of science in the cultural and technological development of the industrial society, and last but not least an understanding of science as a human activity. We believe that these aims can be achieved by letting each book be centered around the evolution of a certain scientific idea through a historic period - long or short - in which the scientific view of the world or the interplay between science, technology and society underwent radical changes. A few examples are:

- The transition from the Ptolemaic to the Copernican world-picture
- Theories of heat and the industrial revolution
- Electromagnetism and the electrification of society
- The transition from classical to quantum physics

Apart form a few well known anecdotes about the great scientists of the past, it is quite common to completely leave out the historical dimension from physics teaching. We are certainly not advocating that physics teaching in general should follow the historic development in any strict sense; that would be an absurd waste of time and even impossible in principle because the students cannot realistically be put into the scientist's situation of say, 200 years ago. We believe, however, that the students should - occasionally - experience physics (or chemistry) as the dynamical science it really is. In science history one can find many good examples to illustrate that a scientific theory which had almost been accepted as a God-given truth, came under an increasing pressure because of the discovery of new phenomena which could not be accounted for by the old theory. Sooner or later the pressure became so intense that the old theory had to be abandoned or at least strongly modified, and a new theory put into its place. But the transition from one way of viewing Nature to another, which may be radically different, is never painless and the transition is not only the result of great scientists objectively searching for the truth. Scientists have subjective sympathies and opinions just like other people and those who have been the strongest defenders of the old theory will usually have great difficulties in accepting the new theory - even long after this has been accepted by the majority of scientists in the field. By studying and discussing a few well chosen examples of this kind the students will hopefully get a feeling for science as a dynamical and very human activity, and they may thus obtain a more realistic view of scientists than the usual stereotyped picture where scientists are surrounded by an aura of almost unlimited authority.

In additon to the above mentioned internal driving forces behind the evolution of scientific ideas the students should also be confronted with historical as well as modern examples showing that the development of science is often intimately connected with the development of society - politically, culturally or technologically. Thus it seems to be a historical fact that the heliocentric system, as put forward by Copernicus in 1543, was used as an argument in favour of the social order which became dominant during the Renaissance, namely the absolute monarchy with the (Sun) King as the central power everybody had to obey and respect. But changing conceptions of the structure appropriate to society were also of critical importance in the acceptance of the new theory of the cosmos. To quote Hutchison[6]:"In renaissance iconography the Sun was a signifyer of Kings, and the Earth a signifyer of man, with the result that important political symbolism was attached to the geocentric and heliostatic world-images. The former represented the medieval ideal of a loosely ordered man-centred monarchy, while the latter represented the baroque ideal of a tightly-ordered monarch-centered mankind. The Ptolemaic theory thus clashed with the ideology of power promulgated by the ascendant centralists of late renaissance Europe. The heliostatic theory, by contrast, appeared to offer divine endorsement. Through this symbolism, a strong prima facie case can be made that political factors were causally implicated in the Copernican Revolution".

As an example of the science-technology interaction we may notice that the modern theory of heat (Thermodynamics) was developed a long time after the steam engine had been invented. Indeed, the working steam engine represented a great challenge to the scientists of the 18th and 19th centuries, and it is thus fair to say that physics owes more to the technological development during the industrial revolution than technology owes to physics. The situation is completely different for electromagnetism, however, since there is a 50 year engineering lag between the discovery of the basic laws of induction and the first working electric generators. The electrification of society could thus never have been achieved without the foregoing intense research in pure science with the sole objective of uniting the two forces of nature, electricity and magnetism. And, as a final example, it is quite obvious that the extremely fast progress in all areas of solid state physics during the last few decades could never have been achieved without the support given by mighty military and economic interests to this field.

Ideas like the ones just mentioned are supposed to penetrate the planned series of books, and hopefully this may then be of help in building a bridge between the two cultures represented by the humanistic and the scientific subjects in the upper secondary school. We certainly have the intention of including in the books a number of connections to other school subjects - history and social science, in particular - in order to facilitate cooperation between subjects which at present have very little tradition for cooperation in the Danish upper secondary school.

Further details about the project

In order to give you a more specific idea about the project and its current status we present below the list of books which are somewhere in the process of evolving from first idea to final product. But it should be stressed at once that we give no guarantee that all the books will be published - and if they do, it may be under other titles than the ones below:

1. The Ptolemaic and the Copernican world views
2. Aristotle-Galilei-Newton
3. From alchemia to chemistry
4. Theories of heat and the industrial revolution
5. Electromagnetism and the electrification of society
6. What is light?
7. The theory of relativity
8. The transition from classical to quantum physics
9. Modern Chemistry and the life processes
10. Man and the universe

Although this represents a rather lenghtly list, it is of course very easy to make it even longer! Thus we must admit that we have so far not included any of such interesting and very up to date themes such as physics and the arms race, the chemical industry and the environment, the development of the transistor, physics and communication etc, etc. All such themes seem very interesting and they would all serve to cast light on the relation between science, technology and society right now, which is certainly of extremely importance. For the time being we think this will have to wait, but may be, we will change our minds.

All the members of the team of authors agree on the main issues of the project but clearly there are also divergent opinions when it comes to details concerning the selection and presentation of suitable material for a particular book. Consequently we have chosen to let each book be written by one or at most two authors, but he (they) will certainly receive a lot of advice, suggestions and constructive criticism from the rest of the group. It is thus unavoidable that the books, when they finally get published, will have different styles, but is this really a weakness? We do not think so, we rather believe that the books may become more fresh and inspiring in the way we have chosen.

We plan to write the books so that most of them can be used already in the first or second year of the upper secondary school. We simply want these books to be read when they fit in with the "normal" physics teaching - we do not want them to be some sort of appendix which the students do not take very seriously. Consequently the physics (chemistry) in the books will be held at an elementary level. We shall concentrate on presenting really fundamental physical concepts and ideas as clearly as possible, and we will not bother to elaborate difficult mathematical formalism.

Finally it should be mentioned that the books will be published by F/K-forlaget, a small non-profit publishing company run by the Association of Physics and Chemistry Teachers.

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SCIENCE, TECHNOLOGY AND DEMOCRATIZATION

- the curriculum of tomorrow?

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Introduction

The concern of this paper is the significance of Science and Technology Education for Democratization. These words are somewhat bombastic. Others have called it education for democratic control. The purpose of this education is to give the student an understanding of Science and Technology which enables her to make decisions in matters about Science and Technology of importance to her future social and vocational life. The considerations are mainly seen from the viewpoint of a physicsteacher and the paper is a preliminary outline.

The understanding of scientific principles has always been considered necessary for understanding and mastery of Technology. It was one of the reasons for implementing Science Education in schools in the last century.

Also in the 1960's, where the progress of Science Education almost revolutionary was advanced, Technology was recognized as an important educational matter. But Technology was only conceived as applied Science. Because Technology is ever changing and developing the rationale of education was to teach the persistent and lasting principles and concepts of Science. The scientific disciplines developed by mankind endowed the future citizen with the necessary knowledge to understand and master Technology.

The scientific method was believed to be the rational and powerful instrument for decisionmaking . For some educators this was not only valid in the context of Science and Technology, but also in the social and political life of the people.

The apparent success of Science and Technology brought along an optimism about future development which influenced the way of thinking in many fields of research and daily life. This optimism is reflected in Science curricula and learning material.

In connection with the risings against authorities of many kinds in the late 1960's the scientific and technological development loaded with expertise was severely questioned. This applies especially in areas like weapons, nuclear power, polluting industries and several other negativeissues of the technological development. A gap between technological optimism and the attitude in people who find themselves alienated and overruled by experts became obvious. Ever since political decisions have be considerably influenced by the debate of the negative issues and consequences of technological development.

Science-teaching and the constitution of Science and Technology.

In spite of the negative attitudes towards Science and in spite of decreasing recruitment to especially Physical Science the changes in Science teaching have been very little since the 1960's. Especially is Technology and technological development still believed to be understandable by application of scientific concepts, principles and theories. Influence on decisions made in the technological field of Society is consequently gained by the aquisition and the mastery of scientific theories and a special scientific way of thinking. The educational philosophy of the disciplinecentered curriculum of the 1960's is still the basic idea in most Science teaching today.

But the critical mind of the student conceives the scientific theories, principles and concepts as detached from reality and Science teaching material reflecting optimism about the technological development as outdated.

Teaching material about Technology explains techniques and technical devices by means of scientific theories. The generation of the teachers was enthusiastic about explanations and was asking questions about "Why". The generation of to day is asking questions about "How it can be used" for planning, for solving practical problems.

The Science teaching of today appeals to students who like to explain and construct. The generation of to day wants to recognize and identify human problems and solve them by means of technology.

The demand for qualifications in the social aspects of Technology is needed with respect to democratization. It is also very much needed by industry.

This does not imply that scientific theories are less significant. On the contrary they are more important than ever, but they are not sufficient neither for the democratization of social life nor for vocational life. The crucial point is the constitution of Science and Technology.

Science and Technology is today a tangled matter, but the endeavour of Science is different from the endeavour of Technology.

The endeavour of Science is knowledge and belief about natural phenomena. The endeavour of Technology is knowledge about human needs.

The intention of Science is "truth". The intention of Technology is relevance to human needs.

Consequently Technology is not understandable without its historical and social context.

The teaching of Science and Technology in the schools.

There are several attempts to overcome the need for Science Education which is not detached from the technological world outside the school. In most countries that kind of teaching are extra-curricular activities. The following is a short and preliminary framework for classification of teaching activities concerning Science and Technology.

1. Technic and technical material.

The teaching material consists of a description of technical topics and technical material. It also may include practical activities like inspection of technical devices and experimentation.

Examples: Motorcars, photography, the nuclear reactor, electronical devices.

The teaching activities may be multidisciplinary, but concentrate on the technical side of a technology. The intention of these activities is usually to make students acquainted with current technology. The activities focus on and are motivated by the technical side.

Some topics are immediately interesting beyond their technical side. This applies to topics like alternative energy or weapons. But they are interesting by virtue of their social and political relevance and not by the technical side.

If this kind of activities is carried out without their social, ethical and political implication they are very short-sighted and of little educational significanceas far as democratization is concerned. If they are furthermore without any significarcefor the learning of basic scientific theories they may end up as isolated, obsolete, almost forgotten knowledge about funny things from an outdated technology.

2. Decisionmaking games.

A decisionmaking game is an artificial scenario demanding a decision, which can be arrived at by following given rules. The game usually contains a simulation representing central features from real life situations.

Examples: To decidewhether to place a polluting industry in an unemployment area or not.

To decide the site of a nuclear powerplant.

To decide how to comply with the need for energy in a hypothetical area.

The scenario in the last example may be a description of an area with a need for energy over a span of time. There also are given the data of several, possible energy supplies. The students then have to discuss and to decide which supply they want and where they want to place it in the area. Although there are some features of decisionmaking present, the premisses for the processare given and mostly the social aspects are very limited and the political aspects and interests are absent. Usually games give the impression that decisionmaking in society is a rational process relying on rational human beings. This fact together with given premisses limits the field of possible decisions.

Although games represent some important features of decisionmaking in society,the mentioned limitations are potential instruments for manipulating the decision of the students.

3. Cases.

Cases are multidisciplinary analyses and examinations of real life situations. They are carried out in order to illustrate special or general characteristics of a technological development. The real life situation is treated in coherence with the historical and social/political background.

Examples: Galilei, Silicon Valley, The Seveso Accident,
The Three Mile Island Accident.

Historical cases are of great significance for understanding technological development. They have an educational potential for future decisionmaking processes. A more direct impact on the decisionmaking by - and opinions of - the students are cases concerning technology in our own time. While the framework of understanding and comprehending historical cases often are well-established, cases from our own time are much more open for social and political valuation.

Case stories have a substantial potential for influencing future decisionmaking, and yet they tend to be controversial. On the other hand cases have a substantial potential for learning about the decisionmaking process.

The material for case stories is normally delivered by the teacher to the student. It is a story, which is told to the student. The way it is told, will of course influence the opinion of the students. This is inevitable and must be realised by the teacher and the student.

4. Projects.

A project is a multidisciplinary investigation by the student into a real life situation. A project differs from a case in the degree of decisionmaking by the student about his own investigation. In a case, the student will get information for the examination of a situation. In a project the student has to gather information on his own. Projects are closer to the real life situation. The topics for projects may be historical or about current matters.

Examples: Noise in a factory. Air Pollution. Heat supply in a local community.

Projectorganized teaching is a powerful educational mean for democratization. Especially current decisions in the local communities, which have a direct influence on the daily life of the citizen, are suitable for projects concerning decisionmaking. The process is going on just outside and the people, who have to make the decisions, are at hand. This provides the students with a real life situation where all the scientific, technical, social, and political aspects can be studied.

In Denmark some schools took the advantage of a current local issue. They organized projects about the energy supply for the local communities. Other problems like watersupply, pollution, conservation of nature etc. are issues for projects as well as global problems.

Curriculum problems with Science and Technology teaching for democratization.

1. Acceptance or democratic control.

The optimism about technological development, which was so obvious 20 years ago, still remains in much Science teaching. Enthusiasm about technical refinements may be more predominant than consequences for the society. Technological development may be represented as inevitable and necessary without any alternative. That kind of teaching may create an attitude of acceptance of decisions made by others rather than the will and the skill to participate in a democratic process of control. The philosophical idea which brings Science and Technology into the classroom is crucial. Because the intention of Technology is relevance for human needs, it is not enough "just to tell the scientific facts". Looking through the 4 categories of teaching activities identified above, the educational potential for democratization is clearly different.

2. Democratization and controversialism.

The 4 categories also differ in their potential for controversialism. The teaching of Science and Technology in a historial, social, ethical and political context will inevitably bring more open political considerations into the classroom. This may be a problem for some teachers and some schools.

3. Multidisciplinarity.

Another problem for teachers and schools may be the multidisciplinarity of the subject. In schools where teachers are specialized in different disciplines, a multidisciplinary approach may be very difficult to establish unless teachers in several relevant disciplines are working together.

4. The impossible syllabus.

Traditionally schoollearning deals with established systematized knowledge. A Science curriculum deals with scientific theories and concepts and includes normally a syllabus. This is possible because Science is dealing with knowledge about nature. The rate of obsolescence is very low. Technology on the other hand is an ever and rapidly developing field. There is no established systemazised knowledge with theories and concepts, because technology is dealing with human needs with the intension of relevance for mankind. It is not possible to give a syllabus. That would be to hand education over to obsolescence. The educational impact of Technology teaching decreases with increasing bindings to a syllabus. It increases the distance from daily life of the students and hence the possibility for the student to discuss on his own about matters of concern.

5. The problem of relevance.

In consequence of the impossibility of a syllabus there is the problem of selecting relevant topics for teaching. Education must have - by definition - some generality, a potential for future citizenship. The general and theoretical content of the learning process must be secured by the teacher.

Especially case-studies and projects may tend to practice without the load of general theories.

By experience students often are motivated by a nearby practical problem. The students may be very enthusiastic about practicising science, interviewing people, discussing local affairs etc. The educational impact is however resting on generalizing their experience and the acquisition of theories. The necessity of theory is not always realized or recognized by the student.

6. The role of scientific theory.

It is not possible to conceive Technology without the social, ethical, and political context. But the social, ethical, and political context without the involved scientific theories is at the most scientific practice and an educational torso. It is to deceive education for democratization to pretend that decisions can be made in society today without the scientific theories. However the learning of scientific theories for application in current and future situations is a very difficult and slow process. Most schoollearning focuses rather on reproduction of theories for shortsighted evaluation then on developing concepts and theories over longer time.

7. Cognitive demands.

Investigations carried out in the last years have shown that the impact of scienceteaching is considerably low. The students cannot master simple daily life-situations by means of Science concepts and theories, which they otherwise should have "learned" in science lessons. Other research has shown that the cognitive demands of scienceteaching exceeds the cognitive capacity of the student. Much more research must be carried out to implement scienceteaching, which is within the cognitive capacity of the student, can be learned by the student and applied to new situations.

A curriculum for tomorrow - a modest proposal.

The problems of scienceeducation today are a great many.

In a time, where Science and Technology become a rapidly increasing impact on the daily life of the citizen, Science education seems to get more and more trouble. The list below applies to Physics

- it is far too difficult
- it is far from reality
- it is irrelevant
- it discriminates girls
- there are too few qualified teachers

Partly because of all these problems scienceteaching and especially physicsteaching carries a far toolow profile.
Science ought to be much more predominant in education.
Science ought to have more lessons.
Science education ought to begin much earlier in schools.

It is possible to introduce science concepts very much earlier, if they are based on the children's own experience and experiments. When the students get older, they will get the capacity to understand more and more of the social, ethical, and political side of Science and Technology. Then multidisciplinary activities concerning Science and Technology ought to be more than extra curricula.

I would like to advance the following modest proposal:

a) Science must have a place in primary teaching.

b) Regular Science and Technology teaching must begin in the 5.grade.

c) Regular Science and Technology teaching must have 2o% of all lessons from the 5. to the 12. grade.

Comment:

In the 5. and 6.grade science ought to focus on basic concepts. All learning ought to be based on the students' own experiments and real life experience.

In the 7. and 8.grade conceptual learning ought to continue, but historical and simple real life cases and small projects may be performed.

In the 9., 10., 11. and 12.grade cases and projects ought to be more predominant, but with the necessity of scientific theories in mind.

On the top of this there may be a specialization especially in the 11. and 12.grade.

d) To achieve the implementation of more and better teaching in Science and Technology, Science teachers must be given better conditions and substantial in-service training in multidisciplinary teaching.

e) The preservice training of teachers in primary and secondary schools must be far more extensive in Science and Technology.

f) Special steps must be taken to promote the teaching of girls and to encourage girls to be scienceteachers.

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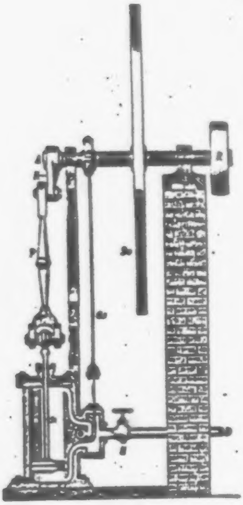
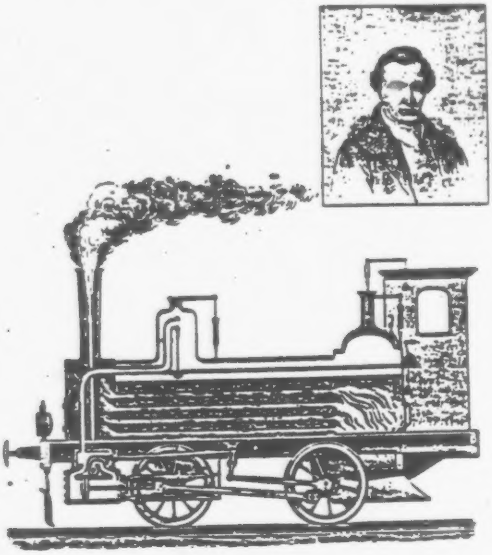
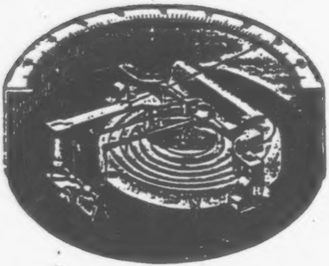
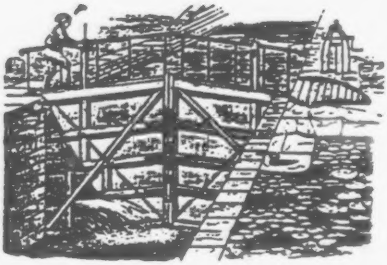
APPENDIX.

Transparencies displayed in connection with the presentation.



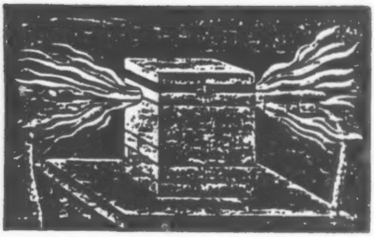


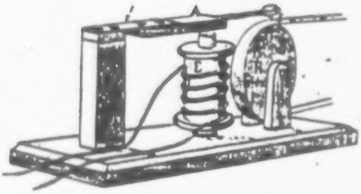


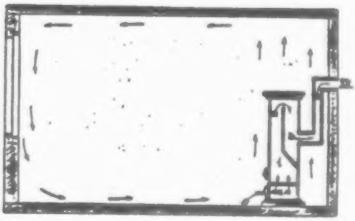


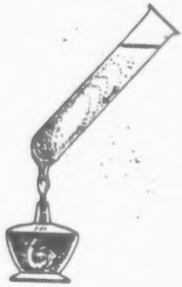
"Technology" in Physics Teaching 1920 - 1960.

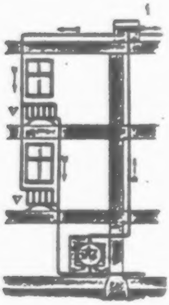
(Rasmussen og Simonsen: Fysik for Mellemskolen. Haase 1920)

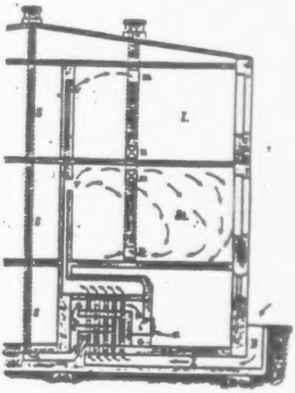


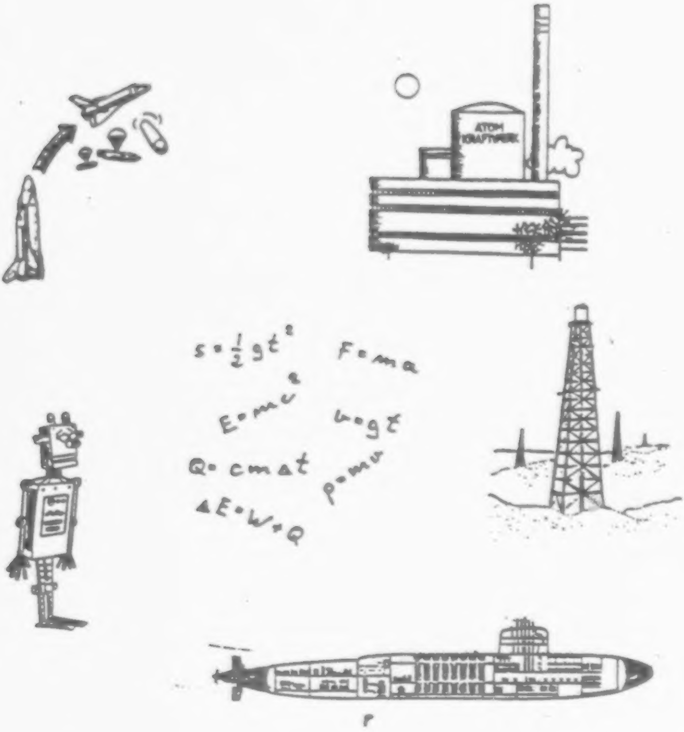











ATOM KRAFTWERK
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F = ma
E = mc²
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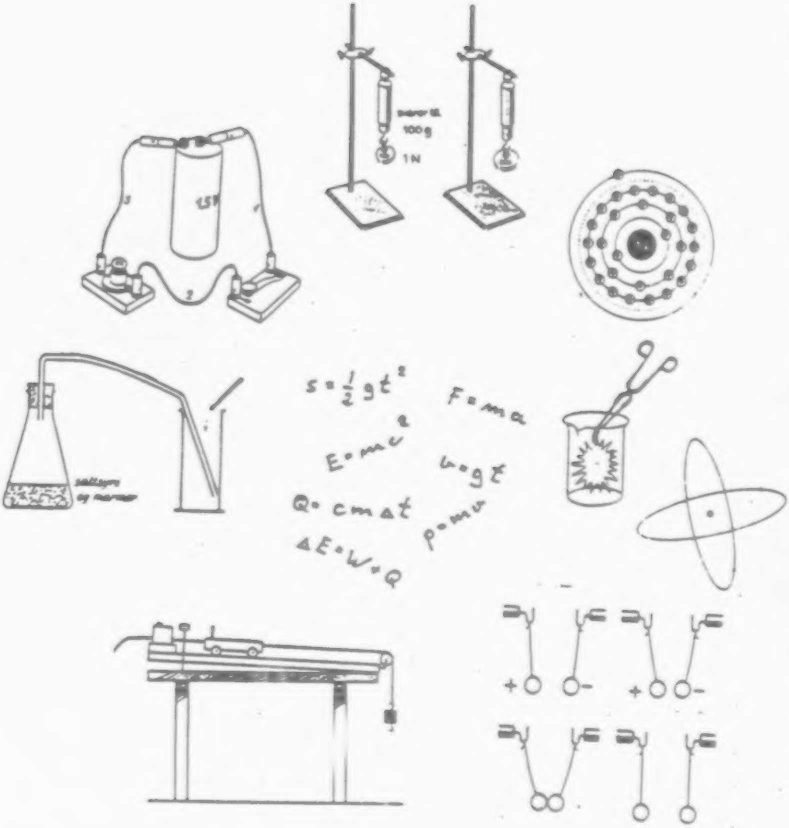
Technology as application of scientific theories.

"What we expect": The mastery of Technology by attained scientific concepts and theories.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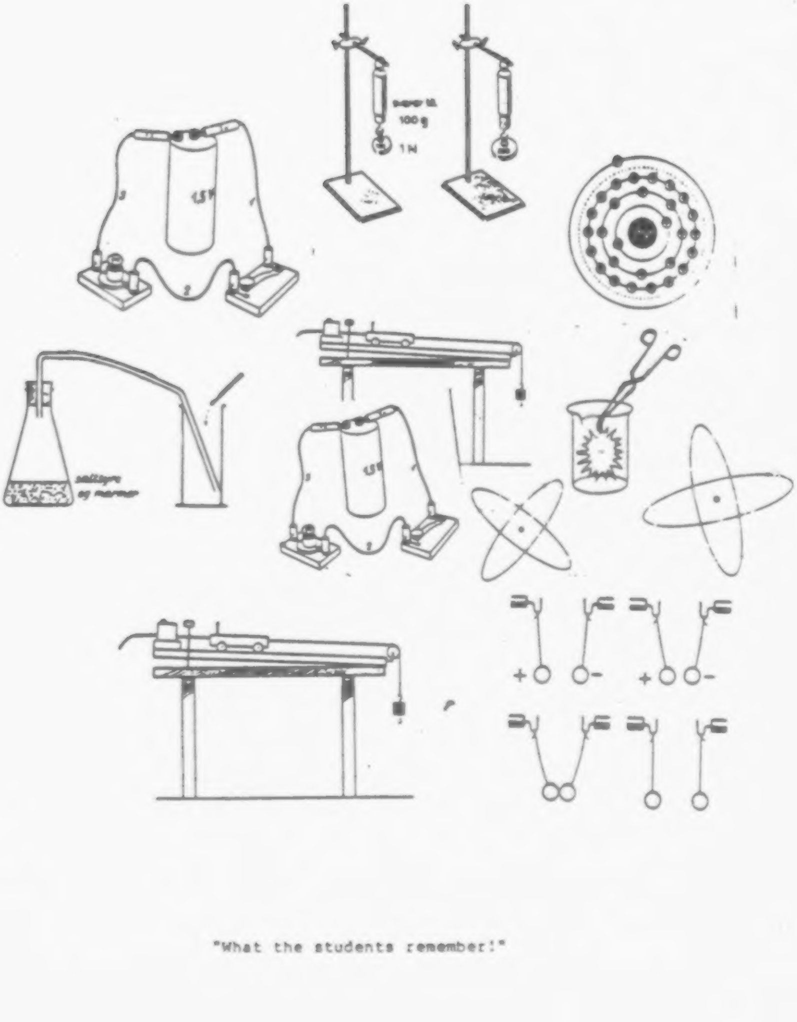
"What we teach!"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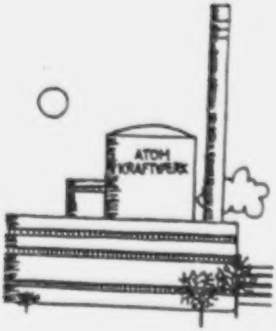
"What the students remember!"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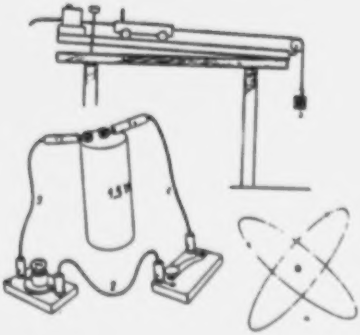

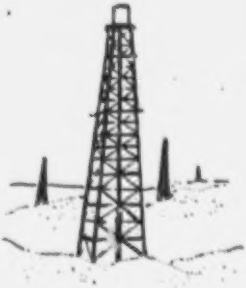

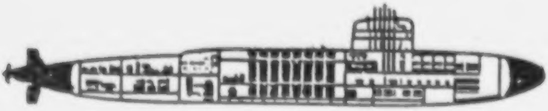

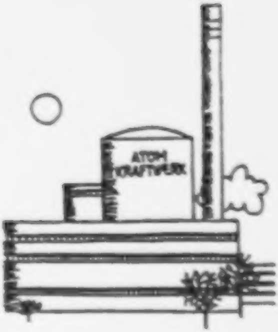
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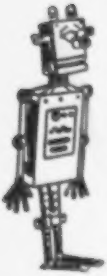

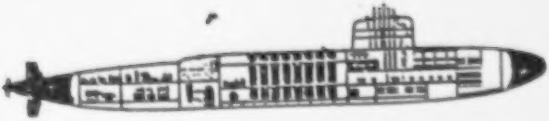

PHYSCIS AND CHEMISTRY EXPERIMENTS WITH VERY SMALL COMPUTERS (ZX81 EQV.)

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Introduction

The use of microcomputers opens up a large area of new topics in physics and chemistry education. In particular experiments of very long or very short duration are carried out very easily thanks to the computer. In mechanics the computer makes calculations on one dimensional movement in a way the students understand, based on the definition of velocity and acceleration. In wave-mechanics, travelling waves and interference is simulated and in radioactivity the decay is simulated and measured. In chemistry, long term measurements on equilibrium system ($Ph(red)+OH^- \rightleftarrows PhOH^-$(colourless) Ph: Phenolfthalein) can be carried out.

The System

The system is based on a very cheap computer, the SINCLEAR ZX81, with a programmable input/output port (INTEL 8255 A or eqv.). The choice is based on the need of low price, a simple programming language (BASIC-) and the clearness of the computers working principles.

The Computer

The ZX81 is available all over the world. It uses an ordinary B&W TV-set as monitor. The databus, addressbus and control signal are available in the back of the computer so it is very easy to connect the input/output port with the computer. ZX81 is programmed in a version of BASIC. Many statements are one-stroke oriented f.inst. touching P on the keyboard the statement PRINT will occur in the line being written. The ZX81 has a built-in clock which can be "read" at the address 16436 and 16437 by using the PEEK statement. The working memory of the ZX81 is only 1K byte but this is enough for many experiments and calculations. A better and more expensive choice could be the very popular COMMODORE 64 which offers a larger memory.

The Port

The circuit 8255A is a programmable triple input/output port. It needs the databus, four controlsignals $\overline{RD}$, $\overline{WR}$ (read, write-active low) RESET and $\overline{CS}$ (chip selected-active low) and two address bits A_0 and A_1. A_0, A_1, $\overline{RD}$, $\overline{WR}$ and the databus are connected directly with the ZX81 expansion port. The RESET control signal from the ZX81 is inverted, and address bit 11 and 14 and memory request MREQ from the ZX81 are combined (and lead) to form the $\overline{CS}$ signal and feed back to the ZX81 control bus as $\overline{RAMC.S.}$ (to prevent mix up of memory addresses). The three ports A, B, and C are "memory mapped" i.e. they are handled as if they were a part of the memory. The addresses are A:20000, B:20001 and C:20002 and the port function is programmed in address 20003 by means of a code (see datasheet for 8255A). This part has been a little bit technical but is of profound interest for those who want to build their own port.

Accessories

Many accessories have been built. A 12 bit binary counter with reset and input gate control, an analog to digital converter (ADC) to measure the voltage on transducers (light, pressure etc.), transmitter and receiver circuit on a fiber-optical link, digital to analog converter (DAC), traffic signal etc.

All the accessories are connected to one or more of port A, B, and C.

....

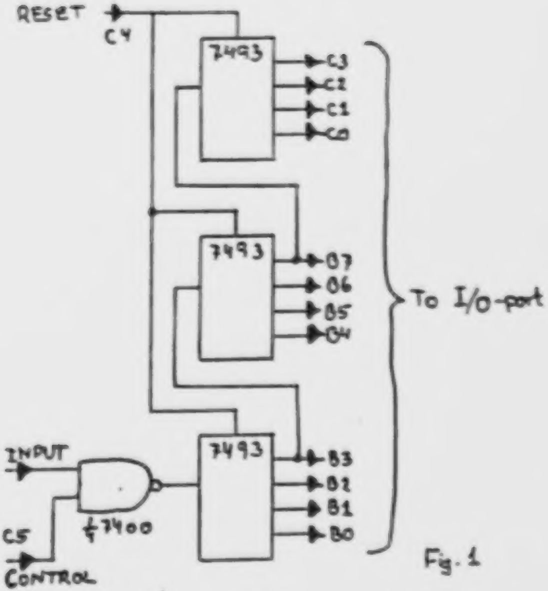
RESET
C4
7493
C3
C2
C1
C0
7493
B7
B6
B5
B4
To I/O-port
INPUT
7493
B3
B2
B1
B0
¼ 7400
C5
CONTROL

Fig. 1

Example

Fig. 1 shows the 12 bit binary counting module. Together with the following programme the system acts as a counter in a experiment where the number of counts in 10 seconds are to be investigated.

10 LET P=20001	(The address of port B)
20 POKE P+2,131	(Port B and the lower four bits of port C are programmed as input and the upper four bits of port C are output. Bit C4 controls the reset function of the counter ahd bit C5 controls the input gate)
30 POKE P+1,16	(Bit C4 high resets the counter)
40 POKE P+1,32	(Bit C5 high opens the gate)

```
50 PAUSE 500                     (500 periods of 20 ms = 10 seconds
                                 pause)
60 POKE P+1,0                    (Close the gate)
70 LET N=PEEK P+256*PEEK(P+1)    (The number of counts is read
                                 by the computer)
80 PRINT N
90 GOTO 30
```

This is the "naked" programme from which the constructor can build on as he wants to do, with the only limitation of memory space and fantasy. It is very simple to modify the programme for special purposes, for instance investigate counting statistics, half-life of a radioactive substance, background etc.

Conclusion

Even a simple system as described above is very useful in physics education on all levels and the low cost benefits the use, especially in developing countries.

THE UNDERSTANDING OF CHEMISTRY AMONG NORWEGIAN STUDENTS

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Research in chemical education

Students understanding of chemical concepts constitutes a new area of research in science education. Johnstone et al.(1) started up in 1970 identifying topic difficulties in chemistry. How are chemical concepts taught? What are the misconceptions? Are certain topics appearing too early in the curricula? Also the theories of Piaget (2) have been of major influence on science education in the last decades. Piaget's work inspires researchers in different ways and mention must be given to Shayer's (3) analysis of the cognitive demands in Nuffield O-level chemistry course. Other researchers like Kempa (4) have investigated concept abstractness levels. Kempa stresses the Ausubelian (5) view that students' ability or failure to solve examination-type problems can be explained in terms of their cognitive structures and what they already know. Rosalind Driver (6) has done research on alternative frameworks. In her book "The pupil as scientist" she emphasizes that children have built up sets of expectations and their own beliefs about a range of natural phenomena and these may differ from those the teacher wishes to develop.

In the Nordic countries research in chemical education is up to now almost restricted to the studies done in Gothenburg. Bjørn Andersson and collegues (7 a,b) have uncovered a series of alternative frameworks in connection with combustion and chemical reactions. In Norway the results from the Second International Science Study, or SISS as we call it, may be the catalysor for future work. This paper will deal with the results from SISS.

The Second International Science Study (SISS)

SISS is one of the current projects directed by The International Association for the Evaluation of Educational Achievement (IEA). The international centre for IEA's SISS-project is the Australian Council for Educational Research (8). SISS was conducted in some 40 countries the last 2 years both in eastern and western countries, in developed and developing countries. As the name indicates there has been a First ISS in which some 19 countries participated in 1971. The aim of both studies has been to develop a map of science education worldwide and thus explore:

- the context within which science education takes place
- the science curriculum
- the teaching and learning practices
- the outputs of the instruction

In order to obtain such a map the SISS-instruments were:

- 3 students' questionnaires w/ multiple-choice tests and attitude questions
- 1 teachers' questionnaire w/ questions on background, possibility for in-service training etc.
- 1 school questionnaire w/ questions on no. of classes in the sciences, students pr class etc.

SISS should try to find connections between the:

a)	b)	c)
intended curriculum as defined by official syllabuses and text-books	translated curriculum as defined by teaching practices	achieved curriculum as defined by students' achievements

The target populations were all 10 year old pupils (pop. 1), all 14 year old pupils (pop. 2) and the last year upper secondary students at pre-university level (pop. 3). In Norway population 1 was defined as pupils in grade 4. Permission was given to let population 2 consist of grade 9 students instead of grade 8, as grade 9 is the last year of compulsory schooling in Norway. For population 3 every secondary school with preuniversity classes were asked to participate in the survey with one group. Population 3 was divided into subpopulations according to the science subject studied at the advanced level: 3 C (chemistry), 3 P (physics), 3 B (biology). There were also subpopulations 3 N (non-science) and 3 M (mixed group of 3 C, 3 B, 3 P and 3 N).

The notations used for the populations of interest in this article are as follows:

4 4th grade students, population 1, no. of students = 1280.
9 9th grade students, population 2, no. of students = 1479.
12 C 12th grade, pre-university students specializing in chemistry, population 3 C, no. of students = 680.
12 N 12th grade, pre-university non-science students, no. of students = 1262.
12 M 12th grade, mixed group of all students at pre-university level, no. of students = 2405.

The SISS-instruments consisted of a core of international items and also optional national ones. The questionnaire for population 3 C for instance, contained in addition to the 30 international core items, 4 Norwegian constructed items.

The results on the chemistry problems will in the following be given as percentage of students responding to each of the 4 distractors and the key question. The percentage of students not responding to the item is written below distractor E.

The results given are preliminary descriptive results. I shall, however, give some comments on the results. As a former teacher I'm always inclined to look for consequences for teaching from surveys and research.

Results

Let us start with an attitude question for population 2:

How do you like science ?

	Well		Indifferently		Poorly	
	boys	girls	boys	girls	boys	girls
Chemistry	43	17	40	41	16	40
Physics	45	14	37	39	17	45
Biology	26	38	49	51	23	10

While some 40% of the boys enjoy the chemistry classes and only some 16% feel a dislike, the percentages were opposite for girls. The results are similar for physics, probably pointing to the fact that chemistry and physics are taught as an integrated subject in Norway at that level. I must add that there is only a slight difference between the sexes on the performance on chemistry problems in population 2.

Chemistry is evaluated as the science subject with the least relevance to daily life. On the other hand, when the students get a practical task from the kitchen, they may not use their school knowledge to solve it. Look at this Piaget-inspired question on conservation:

There is 1000 grams of water in a saucepan. 200 grams of sugar is added. We stir until all the sugar has dissolved.

The content in the saucepan will have a weight of:

Norwegian scores		Swedish scores (ref. 7b)				
4	9	7	8	9		
10.3	2.7	1	1	1	A	Less than 1000 grams
14.5	19.0	10	13	11	B	Exactly 1000 grams
44.9	35.9	23	23	21	C	1000 - 1200 grams
26.9	34.7	62	60	58	D*	1200 grams
3.4	3.8	3	3	3	E	More than 1200 grams
	3.9					

Norwegian item.

These scores might just propose an extensive degree of misconception. But, in fact, we don't know the actual reason why students choose each distractor. A multiple-choice question can only indicate areas of interest for a researcher. A more detailed understanding of the students' ideas may, however, be investigated through interviews. Andersson has used the same multiple-choice question for Swedish students and also interviewed them. The students revealed a set of alternative frameworks causing them to give different responses. Some of the responses were:

exactly 1000 g: sugar disappears, it is only water left,
1000 - 1200 g : the weight of sugar is less when dissolved than as a solid,
more than 1200g: the solution is thicker than water, and solid compounds weigh the most.

The reason for Norway to using the same question is that similar patterns would indicate general statements. There is a saying that chemists always have solutions, but Norwegian chemistry students have probably not found them yet !

With the limitation of the output of a multiple-choice question in mind, we may continue to study some of the answers and look for other areas of interest.

The words "chemistry" and "chemicals" are in some countries almost synonymous for poison and danger. Was the situation similar in Norway ? We wanted to test the hypothesis that students distinguish between natural substances and chemical substances, and that students consider chemical substances to be harmful. This item was therefore given to all three populations:

					Which one of the following sentences expresses a correct statement?
4	9	12 N	12 M		
34.8	20.6	20.2	11.3	A	Chemical substances do not belong in nature. Man has made them.
14.4	9.1	4.6	1.2	B	Natural substances can't be harmful.
25.6	18.2	11.7	4.3	C	Chemical substances are usually harmful.
10.8	28.1	43.7	73.5	D*	Natural substances are also chemical ones.
14.2	22.1	18.7	9.1	E	Natural substances are composed of atoms while chemical substances are composed of molecules.
	1.8	1.1	0.6		

Norwegian item

Among the youngest students the opinion that chemical substances are manmade was the prevailing one. Tuition or just the effect of aging, increases the percentage of students selecting the key question (D), but even pre-university students think of chemical substances as not belonging to nature. Attention should also be given to the 9th grade, distractor E. The students probably think that a question on chemistry must be answered in terms of atoms and molecules. We have seen the same tendency in other surveys too.

Are the mass-media to blame for the bad image of chemistry? You may look at 2 of the 4 pages on chemistry in a Norwegian text-book on theoretical subjects for grade 6. (Page 8) The heading is Poison and the text reads:

> "Some years ago it was customary to have chemical toilets in our cottages. People used chemistry substances to get rid of the smell. Chemistry substances don't belong in nature. Man has made them artificially. But nature wan't have anything to do with these synthetic substances. They do damage to the nature."

This was an example of how chemistry is presented in the text-books. I might add that the author is a journalist and not a scientist.

Andre farer lurer på livet i sjøen

Gift!

Det er ikke sant at sjøen er utømmelig. Men er det sant at den er den beste søppelkassa i verden, da? Mange har lenge trodd det. Det er jo så god plass i sjøen. Og så ser vi ikke mer til det vi kaster uti. Slik tenkte vi lenge.

På ei koselig hytte-øy utenfor Mandal var det for noen år siden vanlig at feriefolket tømte hyttedoene sine i sjøen før de drog hjem igjen. De hadde tørrklosett, og de hadde brukt *kjemiske stoffer* til å fjerne lukta. Kjemiske stoffer hører ikke til i naturen. Det er menneskene som har laget dem på kunstig måte. I 1920 var det noen få slike stoffer i havet og innsjøene på jorda. I dag er det flere tusen av dem.

Folk reagerer så ulikt på dette bildet. Noen ler, andre blir redde. Hva tenker du?

Nå tømmer ikke folk tørrklosettene sine i sjøen lenger. Vi vet mer om hvordan de forskjellige kjemiske stoffene virker på livet i naturen. Før trodde vi at naturen tok seg av slike stoffer, brøt dem ned og laget dem om til nyttige stoffer.

Avfall som hører til i naturen, blir brutt ned og laget om til nyttige stoffer. Men naturen vil ikke ha noe å gjøre med de kunstige stoffene. De gjør skade på naturen.

Det fins også giftige stoffer i naturen. De kan være farlige for livet hvis de blir brukt i andre sammenhenger enn det som er naturlig. Et slikt stoff er *kvikksølv*.

Kvikksølv blir blant annet brukt i termometre. Det er et sølvgrått stoff, og dersom du knuser et termometer, vil du se at det triller av sted som små kuler.

OPPGAVER

Tenk deg om!

1. Kaster du avfall i sjøen? Vet du om andre som gjør det?
2. Er det bare kjemiske stoffer som ikke bør kastes i sjøen?
3. Er sjøen den beste søppelkassa i verden, eller er det ikke slik? Begrunn svaret ditt.
4. Hvorfor bør en ikke knuse et kvikksølvtermometer?

En fæl historie

Det vi skal fortelle nå, skjedde for mange år siden i et land langt borte. Du kan likevel ikke være helt sikker på at noe lignende ikke kan skje her.

I den lille japanske fiskerlandsbyen Minamata oppdaget folk en gang i 1953 at kattene begynte å oppføre seg så merkelig. De sjanglet av sted, gjorde underlige rundkast og gav fra seg rare lyder. Ja, noen av dem så ut som de var fullstendig fra vettet. De hoppet like lukt på sjøen. Og du vet jo hvor redde katter er for vann! Folk lo av kattene og spøkte med at de hadde drukket seg fulle.

Men så ble det plutselig alvor. Noen av barna i byen – for det

Let us take another example on chemistry in society:

You hear all sorts of things about acid rain, but what is correct?

9	12 N	12 M		
26.6	6.9	6.1	A	There should have been no acid rain if all factory smoke was cleaned.
19.6	45.3	61.3	B*	Combustion of sulphur-containing compounds as coal and oil will later result in acid rain.
23.5	27.8	23.9	C	Acid rain is rain or snow containing a fine powder of sulphur.
22.4	18.0	7.9	D	Acid rain is actually caused by acid-output from industry. Acid evaporates and precipitates as acid rain.
6.2	0.8	0.4	E	The increasing amount of acid rain over southern Norway has no effect on the acidity of the water-courses.
1.7	1.2	0.4		

Norwegian item.

The chemistry on how acid rain originates is certainly not fully understood. We may ask whether it matters if the students can distinguish between acidic precipitation consisting of elementary sulphur, sulphur dioxide or sulphuric acid? We may also ask whether it matters if they blame industry for all acid rain and pollution. Anyhow, looking at the next item might suggest that sulphur dioxide in some way is connected in their minds with acid:

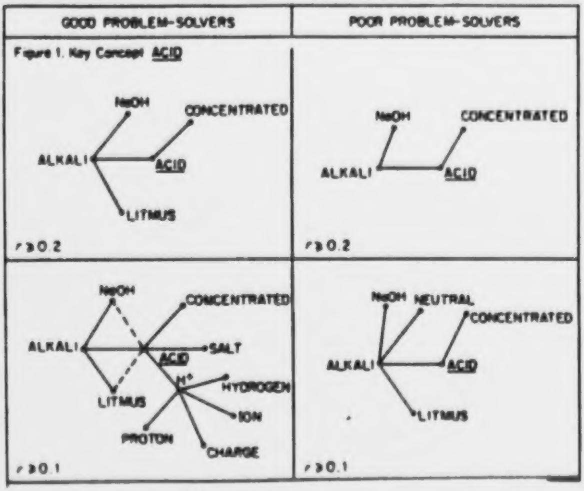
Which one of the following formulae represents sulphuric acid?

9	12 N	12 M		
3.8	4.1	3.8	A	HCl
62.1	46.4	8.4	B	SO_2
2.6	2.0	1.3	C	HNO_3
25.1	42.9	86.8	D*	H_2SO_4
3.9	3.2	0.6	E	NaCl
2.5	1.9	0.2		

Norwegian item

What may be read from this item is that most of the students in grade 9 do not connect an acid with a compound containing a hydrogen atom in the formula. Kempa and Nicholls (4) used controlled word association tests to develop how strongly different concepts were held in the cognitive structures of the students. They demonstrated that theoretical abstract concepts as proton and ion are absent from the cognitive structures of poor-problem-solvers aged 15. The relatedness coefficient (r) is a measure for how strongly the concepts are connected to each other in the cognitive structure of the student. The greater r is, the stronger the connections.

Figure 2. Average cognitive structure display for the chemical concept acid, obtained for good and poor problem-solvers. (Kempa & Nicholls 1983)


GOOD PROBLEM-SOLVERS
POOR PROBLEM-SOLVERS
Figure 1. Key Concept ACID
NaOH
CONCENTRATED
ALKALI
ACID
LITMUS
r ≥ 0.2
NaOH
CONCENTRATED
ALKALI
ACID
r ≥ 0.2
NaOH
CONCENTRATED
ALKALI
SALT
ACID
H+
HYDROGEN
LITMUS
ION
PROTON
CHARGE
r ≥ 0.1
NaOH
NEUTRAL
CONCENTRATED
ALKALI
ACID
LITMUS
r ≥ 0.1

Matthews and al. (9) conducted cognitive mapping and demonstrated that many students do not combine proton with hydrogen and that these concepts are virtually far from the concept of acid.

What is the situation then for the 12th grade Norwegian students specializing in chemistry? Most of the students are probably abstract-thinkers, but do they possess a firm knowledge and understanding of acids and bases? The following two items on the alkalinity of oxides are very similar:

Which one of the following elements forms an oxide which turns red litmus paper blue when added to water?

12 C		
10.3	A	phosphorus
13.7	B	carbon
7.5	C	iron
25.6	D	sulphur
39.0	E*	calcium
4.0		

International item

Which of the following would be described best as an oxide could only be basic?

12 C		
7.4	A	Al_2O_3
7.9	B	CO
17.9	C	P_2O_5
15.6	D	NO_2
44.3	E*	CaO
6.9		

International item

As you may see, the idea that oxides of non-metals usually give acidic solutions in water, and that oxides of metals usually give alkaline solutions, is not commonly held by the students. It might be that the oxides of which they are familiar have been chosen, no matter the context. The implications for instruction probably include practical work. But does it help? :

A 15.0 cm^3 sample of a 1.00 M ($mol.dm^{-3}$) solution of hydrochloric acid (HCl) will exactly neutralize 7.5 cm^3 of a 1.00 M solution of which one of the following substances?

12 C

11.3	A	sodium hydrogen carbonate: $NaHCO_3$
19.6	B	potassium hydroxide: KOH
2.6	C	ethanol: C_2H_5OH
55.9	D*	barium hydroxide: $Ba(OH)_2$
6.2	E	magnesium chloride: $MgCl_2$
4.4		

International item

Titration of acids with bases are compulsory practical experiments for the 12th grade chemistry students. Calculations from these experiments are often given in the final written examination papers. The scores on this question can certainly not be taken to confirm the central position of titrations in our Norwegian curriculum.

What does really happen during neutralization, the next question runs:

In order to neutralize 2 mols of NaOH we may use 1 mol of an acid (acid A, acid B or acid C). Which one statement is then always correct?

12 C

6.3	A	Acid A, acid B and acid C have equal pH's.
50.1	B	pH in the neutralized solution is 7.
5.3	C	The concentration of the acid-solution is double the concentration of the hydroxide-solution.
13.8	D*	One mol of the acid contains two mols of hydrogenions.
5.3	E	The volum of the acid-solution needed is half the volum of the hydroxide-solution.
19.1		

Norwegian item

Most students chose distractor B which says that pH in any neutralized solution is 7. The idea that the acid must have two mols of hydrogenions (D), is held by rather few. If this concept of an acid is not present in the cognitive structure of the student, he should not be able to solve the former question on neutralization of 15.0 cm^3 1.00M HCl either. Difficulty might arise when the student consider the ordinary use of the word "neutral" meaning neither acid nor base.

Do students really have a grasp of chemical reactions? The distractor of highest score on this item is that of neutralization (E):

Which type of reaction is represented by the equation

$CH_3CH_2OH + HCl \rightarrow CH_3CH_2Cl + H_2O$

12 C

45.0	A*	Substitution
7.4	B	Elimination
7.9	C	Redox
7.9	D	Condensation
13.7	E	Neutralization
18.1		

Norwegian item

The last five items were all answered by 12th grade students specializing in chemistry. Let us return to the 9th graders. Their understanding of the nature of chemistry is rather wage:

When 2 g (grams) of zinc and 1 g of sulphur are heated together, practically no zinc or sulphur remains after the compound zinc sulphide is formed. What happens if 2 g zinc are heated with 2 g of sulphur?

9

29.0	A	Zinc sulphide containing approximately twice as much sulphur is formed.
19.5	B*	Approximately 1 g of sulphur will be left over.
5.2	C	Approximately 1 g of zinc will be left over.
11.6	D	Approximately 1 g of each will be left over.
31.5	E	No reaction will occur.
3.2		

International item

The atomic structures and electron configurations for the first 20 elements are part of the core curriculum in chemistry for the 9. and 10. graders. If students have a grasp of the ideas of the periodicity of elements and of the periodic table, they may presuppose chemical reactions. These items show the Norwegian students' conception of elementary particles and the periodic table:

Which of the following particles are gained, lost or shared during chemical changes?

9	12 N	12 M		
29.0	46.8	84.0	A*	electrons furthest from the nucleus of the atom
14.7	11.7	3.5	B	electrons closest to the nucleus of the atom
24.5	20.3	4.5	C	electrons from the nucleus of the atom
13.9	8.4	4.1	D	protons from the nucleus of the atom
9.3	9.2	2.4	E	neutrons from the nucleus of the atom
8.6	3.7	1.6		

International item

For the next item you shall use this part of the periodic table of elements:

I	II	III	IV	V	VI	VII	VIII
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K Kalium	20 Ca						

Below there are 5 sentences about potassium ("Kalium"). Which one is not correct according to potassium's position in the periodic table?

9	12 N	12 M		
11.7	15.8	4.2	A	Potassium reacts easily with an element in group 7 (VII)
12.5	11.7	6.0	B	Potassium does not react with an element in group 8 (VIII)
23.4	24.2	73.3	C*	Potassium reacts easily with another element in group 1 (I)
27.3	25.1	9.2	D	Potassium is a metal
18.1	20.5	6.9	E	Potassium has one electron in the outer shell
6.9	2.7	0.4		

Norwegian item

Chemistry is a foreign language twice over, strange terms for strange things. Why do chemists say CH_3COOH for vinegar? The lack of understanding of the chemical formula of an acid (sulphuric acid) has already been demonstrated. Here we have another example:

The formula for the compound acetic acid (present in vinegar) is CH_3COOH.

What is the total number of atoms in one molecule of acetic acid?

9		
1.2	A	1
3.6	B	2
34.4	C	3
21.9	D	6
36.9	E*	8
2.0		

International item

Formula notations are used in the textbooks for lower secondary school, grade 9.

Text-books for the students specializing in chemistry in grade 12 are full of formulas, and the IUPAC system of nomenclature is used. The authors and the teachers write and talk about sulphide, sulphite, sulphate, thiosulphate .... hardly without any prescription on how to name these substances.

Calsium is in the second group of the periodic table. The formula for chloric acid is $HClO_3$, for chlorous acid $HClO_2$ and for hydrochloric acid HCl.

Which of the following formulae is the correct one for calsium chlorite?

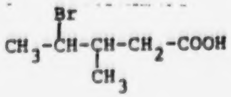
12 C		
19.7	A	$CaClO_3$
10.4	B	Ca_2ClO_2
19.6	C*	$Ca(ClO_2)_2$
9.3	D	$CaCl_2$
18.1	E	$Ca(ClO_3)_2$
22.9		

Norwegian item

The results of the SISS-tests are in accordance with my own supposition. I think that you have to give recommendations or "grammar rules" if a foreign language may be read and written fluently.

The next item asks for the systematic name of a brominated carboxylic acid.

What is the systematic name for this compound using the IUPAC-nomenclature?



$CH_3-CH(Br)-CH(CH_3)-CH_2-COOH$

12 C		
10.9	A	3-bromo-2-methylbutanoic acid
15.0	B	2-bromo-3-methylbutanoic acid
25.7	C	2-bromo-3-methylpentanoic acid
14.0	D	3-methyl-4-bromopentanoic acid
15.4	E*	4-bromo-3-methylpentanoic acid
19.0		

Norwegian item

There seem to be no result on this question when corrected for guessing. The items on nomenclature were the last two items in the questionnaire, which to some degree explains the high percentage of students not having given any response.

Conclusions

These preliminary results from the Norwegian survey in the Second International Science Study show discrepancies between the intended curriculum and the achieved curriculum. The responses to the multiple-choice items in the students' questionnaires allow us to identify areas of marked weakness in comprehension among our students. In order to obtain a better understanding of the conceptions, misconceptions and alternative frameworks held by the students, further investigations have to be done. Let this be the great challenge for the Norwegian chemistry-educators in the future .

SISS in Norway

The Norwegian survey as part of the Second International Science Study was financially supported by the Norwegian Department of Education (Kirke- og Undervisningsdepartementet). The Norwegian survey was conducted by IMTEC (The International Learning Cooperative) in Oslo, with Svein Sjöberg at the University of Oslo as national research coordinator. Official reports will probably be due by the end of 1985 as several books on Universitetsforlaget.

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A MODEL FOR SELF-RELIANCE IN SCIENCE EDUCATION RESOURCES

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Delhi-110007 (INDIA).

INTRODUCTION

The Division of Scientific Research and Higher Education, Unesco and the Committee on Teaching of Chemistry (CTC) of the International Union of Pure and Applied Chemistry (IUPAC), has sponsored a pilot project at the University of Delhi for design and fabrication of low-cost equipment for chemistry teaching. The nature and scope of the project is first summarized followed by a highlighting of its key features. The article concludes with a glance at some of the possibilities for the future.

THE DELHI PROJECT

The Problem:

The laboratory component of chemical education in the developing countries is deteriorating because of the

- continual rise in the cost of chemicals and equipment;
- black-box attitude towards instruments resulting in poor maintenance.

The diminishing quality of laboratory work will

- prevent learning of manipulative skills;
- produce chemists ill equipped for research teaching and industry.

A Solution:

Modern technology, particularly in electronics, offers many products which are

- cheap, verstile, long-lasting;
- new made or are available in the developing countries;
- usable as building blocks for design of simple equipment.

An Approach:

A problem, however, can seldom be solved by technology only. Methodology is thus equally important. If reliable low-cost equipment (i.e. equipment low in cost but not in quality) is to become a means of improving chemical education, it is essential that teachers and students are involved in the developmental process, i.e., in the design, fabrication and testing of prototypes. This will ensure that

- the equipment is tailor-made for different requirements;
- confidence and expertise in instrumentation is generated;
- overheads are negligible;
- maintenance is satisfactory.

A Pilot Project:

A pilot project at the University of Delhi has established the feasibility of this plan of action. The project sponsored by the Committee on teaching of Chemistry (CTC) of the IUPAC, in collaboration with UNESCO and the Committee on Teaching of Science (CTS) of the International Council of Scientific Unions (ICSU), has so far designed low-cost versions of the following types of equipment (cost price as of January 1985 (1 US Dollar = Rs. 13 approximately); pH meter (8 versions ranging from Rs. 125 - Rs. 400); conductometer (4 versions ranging from Rs. 75 to Rs. 350); colorimeter (Rs. 400); polarimeter (Rs. 75); electronic timer (Rs. 100); magnetic stirrer (Rs. 150); electronic thermometer (Rs. 25, if used in conjunction with the pH meter); conductance cell (Rs. 20); a set of nearly zero-cost electrodes (includes glass electrode and some ion slective electrodes).

Preliminary versions of a D.C. polargraph (Rs. 600), spectrophotometer (Rs. 300), Galvanostat (Rs. 300) have been produced.

The key features of the project are

- use of modern devices like an operational amplifier;

- total reliance on indigenous components;
- interdisciplinary nature of the core group;
- voluntary participation of students and and teachers during holidays;
- development of integrated low-cost packages (i.e. equipment, accessories and experiments).

Propagation:

The philosophy of the project is to spread the approach rather than distribute or sell the instruments. The following training Workshops - devoted to low-cost potentiometry and conductometry - have been held: Madras (April and July 1981); Mysore (1981); Delhi (1982), Hyderabad (1982); Chandigarh (1983); Sao Paulo, Brazil (1983); Georgetown, Guyana (1983); Copenhagen, Denmark (1983); Montpellier, France (1983); Dhaka, Bangladesh (1984); Sri Lanka (1984); Bathurst, Australia (1984); Dhaka (1985).

Twenty-four instruments assembled in Bangladesh and Sri Lanka are being used in the host countries.

For 1985, Workshops are being planned in Ljubljana (Yugoslavia), Puerto Rico, and in Pakistan. Over twenty institutions in India have been using the equipment (pH meters and conductometers) for a year and have sent their evaluation which is very favourable.

Key Features:

(i) International collaboration: The sponsorship of professional organizations (like the IUPAC) for prototype activity provides expert scrutiny and opportunities for a global exchange of information.

(ii) Total reliance on indigenous components: With the rapid development of the industrial infrastructure in the country, it is possible now to undertake developments, based on modern approach and latest technology, that are cheep, versatile and powerful.

(iii) Interdisciplinary nature of the team: A joint effort by chemists, physicists and technicians enables a balanced consideration of theoretical and practical matters and of fundamental and applied aspects. If the project expands, scientists from other branches and engineers can be appropriately coopted.

(iv) Participation of students and teachers: This creates a sense of involvement besides generating confidence and expertize required for more ambitious developmental efforts. The ability to modify, maintain and repair routine equipment, is an important off-shoot.

FUTURE

All the ideas on which the Delhi Project is based are well known. No originality can therefore be claimed on this count. However, to the extent that the laboratory component of science education is deteriorating in the developing countries, it is clear that there is an urgent need to extend such activities. There seem to be at least two ways of enlarging the scope of the Delhi Project.

Firstly, it may be pointed out that the model utilizing teachers and students on the one hand and on linking training with production on the other, is not limited to fabrication of equipment only. The model is for example also applicable for preparing such chemicals as are needed for science education but are being imported or are difficult to make on industrial scale. Similarly, providing facilities like distilled water, gas, power for rural as well as urban science institutions on a laboratory scale using solar distillation, bio-gas etc. are exciting technological problems. Another area is generating audiovisual material like charts, tape-slides, videotapes, films etc.

and development of demonstration apparatus which can be housed in small museum in each University/College for the benefit of non-science students and the public at large. It should be possible to start pilot projects in one or more of these areas alongside propagation of the low-cost equipment as these different areas are interlinked and can be pursued together.

Finally, there is a need to involve more countries in such efforts. There is also a need to involve more students and teachers in each country. Such an extension obviously demands that more funding agencies - both national and international - initiate cooperative programmes. An interesting model in this connection is that of Regional Cooperation. For example, it will be worthwhile to explore whether the Nordic group of countries and the South Asian group can launch a three to five year plan for science and technology Education where Resource Material (e.g. Equipment, Chemicals, Software, Videotapes, etc etc) is produced using the methodology adopted in the Delhi Project. If one such cooperative venture is successful, it can serve as a model for extending it to the other regions of the World. It is hoped that the Nordic Conference will give a serious thought to this suggestion.

ACKNOWLEDGEMENT

It is a pleasure to acknowledge the enormous assistance received from Prof. D.J. Waddington (IUPAC) and Dr. J.V. Kingston (Unesco) at every stage of the Delhi Project. Thanks are due to the Unesco Regional Office, New Delhi, for providing travel funds to attend the Nordic Conference. Last but not least, I am sincerely indebted to Prof. Erik Thulstrup for the kind invitation and the warm hospitality.

AN EMPIRICAL INQUIRY OF PUPILS' CONCEPTIONS OF BLOOD AND BLOODCIRCULATION.

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Department of Biology,
University of Oslo.

This project is Beeing undertaken for partial completement of a Master of Science degree at the Department of Biology.

Supervisor: Olav Sand,
Skolelaboratoriet for biologi,
University of Oslo.

Introduction

Learning is not a passive process of absorbing knowledge,but one of modifying and restructuring existing ideas by the pupils.
These ideas often come from the pupils own experiences, and may be very different from the scientific ones.
They are often called alternative frameworks.
The same ideas are often shared by many people.
The ideas will influence what is learnt in a lesson, and therefore, it is important to know something about them.

In the last years, different groups at Skolelaboratoriet for naturfagene,University of Oslo, have been trying to uncover alternative frameworks in the natural sciences.(Sjøberg,S & Lie,S,1981, Bryhni,E & Sand,O,1983).
I,beeing a student in the Physiology group, have chosen to study pupils conceptions of blood and bloodcirculation.

When making the inquiry, my basis was this :

1. Yesterdays science is often todays alternative frameworks.
   Concerning blood,people used to think that blood was produced in the heart, pumped out to the body and consumed there.

2. What is written and drawn in the textbooks.
   Pilottests have indicated that very schematic drawings lead to misconceptions.

Methods.

I. SISS (The second International Science Study).
This is a test for pupils at age 10, 15 and 18, with multippel choice questions.
In Norway, about 1500 pupils are tested at each age. One third of the test is national, and in the Norwegian part we have made about 8 questions concerning blood and circulation. During April we hope to have all the data from this test.

II. One of the limitations of multiple choice questions is that one has to suspect exactly which the alternative frameworks are to make the right distractors. Therefore, I will make a new test with open-ended questions which will be given to a few hundered pupils at age 15.

III. Interviews.
In this part I will interview some of the pupils who answered the open-ended questions, trying to pick out the pupils showing alternative framework thinking.

The inquiry will be finished during autumn 1985.

DIFFERENCES IN GIRLS' AND BOYS' ATTITUDES TOWARDS SCIENCE - A STUDY AMONG THIRTEEN-YEAR-OLD PUPILS IN HVIDOVRE/DENMARK WITH A VIEW TO DEVELOPING STRATEGIES FOR CHANGES.

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DK-2635 Ishøj,
Denmark.

Summary

The paper will include an empirical study carried out among 600 seventh-class pupils in the Danish primary school.

In this class these thirteen-year-old children are for the first time confronted with the physical and chemical training and education.

One of the purposes of my studies has been to learn something about sex-linked differences between girls´ and boys´ interests and attitudes towards physical and chemical science.

Another purpose is to develop a teaching programme which can secure a less differentiated education during the pupils´ first year with psysics/chemistry.

The study is part of my psycological-pedagogical education at the Royal Danish School of Educational Studies, Department of Chemistry.

Background

In Denmark pupils are confronted with their psysical and chemical education when they are 13.

The Danish school system has a primary school which starts when the children are 6 or 7. The pupils continue to go to school in the primary school till they are 16 or 17, i. e. 9 years´ compulsory school.

The socalled ´kindergarten´ class which has only three lessons per day and which is the pupils´ first class is not compulsory but attended by almost every child.

It is possible for the pupils to leave school after their ninth year when they can either have a further education at grammar school or they can choose to start an apprenticeship. They may also stay an extra year in the primary school.

From the 7th till the 9th school year the subject of ´psysics/ chemistry´ is compulsory with two lessons per week. The subject may also be continued in the 10th school year.

For 14 years I have been teaching physics and chemistry at the Danish primary school.

Over the past years we have seen a rapid development in our society, and many innovations have been introduced in the schools. The style of teaching has changed from being theorical to being practical, and the work has developed to be more pupil-oriented.

In my teaching period, however, I have only seen remarkably little change in the sex-linked attitudes and expectations to physical and chemical science.

Already at their seventh year at school many girls expect themselves to do very bad in this subject.

Results published in the UK, Norway and Denmark show that on average boys achieve higher marks in physics/chemistry than girls do.

By the time they start the subject most girls already know that it is an unwoman one. They are brought up to be feminine beings, and their surroundings - parents, teachers, playmates, literature - have told them that girls are more verbal, less independent, more interested in individuals - and less interested in physics/chemistry, more modest in their wishes for the future and less experienced in science-related activities than boys.

The Study

As part of my psycological / pedagocical education in chemistry at the Royal Danish School of Educational Studies I have decided to carry out an empirical study among seventh-class pupils in a Danish primary school. My study will be the first of its kind in Denmark dealing with sex-linked differences within the subject of physics or chemistry.

The study has been carried out among 531 seventh-class pupils in Hvidovre, a southern Copenhagen suburb.

The purpose of my study is to show some sex-related differences between the interests and attitudes of girls and boys which may influence their future achievements within psycical and chemical science.

The questions asked about attitudes and interests, and the questions about relevant experience within psysical and chemical science are very much like those in the Norwegian project: "Jenter og fysikk" mentioned in the Contributions to the second GASAT Conference.

Questions about Pupils´s Interests

In the questionnaire I have included a number of subjects which may be part of the physics/chemistry teaching. The pupils were asked to indicate whether they found it important or exciting to learn about.

The results appear from tables 1 - 6.

It appears that the pupils have distinguished between ´exciting´ and ´important´; Well over half of the girls found it exciting to learn about the rainbow, for instance - few of them, however, have considered it important to learn about. Few (8 or 9) of the subjects a majority of the girls has found exciting or important (table 3 and table 6) such as natural phenomena, additives to food, and pollution.

Most of the seventh-classes had learned about/worked with electricity in the class during some time before the investigation was carried out, and many of the pupils indicate that electric current and electricity as such are important subjects at home, but apparently it is not very exciting.

I am, as yet, not quite sure how to use the information available in this material. As a prelimary conclusion, however, I would say that it is important to emphasize those phenomena at which the pupils are astonished, and which are important for their conception of their daily lives.

Experience within Physical and Chemical Science

In a number of cases the pupils were asked to indicate how often they had been doing this or that.

The spaces ˝once or twice˝ caused most of the pupils to ask questions. In these cases I told them to make out whether they had tried the particular thing often enough to know how to do it next or whether they had tried to do it only once.

Only few activities have been done by both girls and boys - such as tape recording, usage of calculator, photographing. Girls are experienced in domestic activities; boys in the activities that are often included in the traditional physics lessons. See tables 7 and 8.

In general, the girls are not as experienced as the boys are in the various activities (table 9), and it is only few ˝girls˝ activities˝ which - according to the boys˝ answers - have never been tried by the boys. Boys generally ˝try˝ more than girls.

So the boys are much more experienced in technical fields thus being better able to relate the theories of the physics teaching to their own experience.

The pupils˝ opinions about what is girls˝ activities and what is boys˝ activities are surprisingly conservative (table 10). However, it is very well in line with what girls and boys actually indicate as their everyday activities. I would like to point out, however, that although the computer is not indicated by the girls to be a pronounced ˝boys˝ activity˝, this is not in line with the fact that far more boys than girls have been using it regularly.

What will be important for your future job?

The pupils were asked to indicate the factors that they thought most important for their future occupation.

The seventh-class pupils expect their future job to be exciting providing also a safe future. Furthermore, their qualifications must be utilized in the job - the job must also make it possible for them to spend sufficient time with their family.

It is hard for me to imagine jobs providing equally high priority to all four wishes. It is worth noticing that both girls and boys agree to this priority (table 11.a + b).

However, already in the pupils' seventh class it is possible to see the pattern of their later choice of occupation. Girls often want to help other people and to have to do with other human beings in their job, while the boys - to a wider extent than the girls - give priority to the things that are important to become a manager, i. e. to control others, to decide themselves what to be done, to make inventions, and to earn much money (table 11.c).

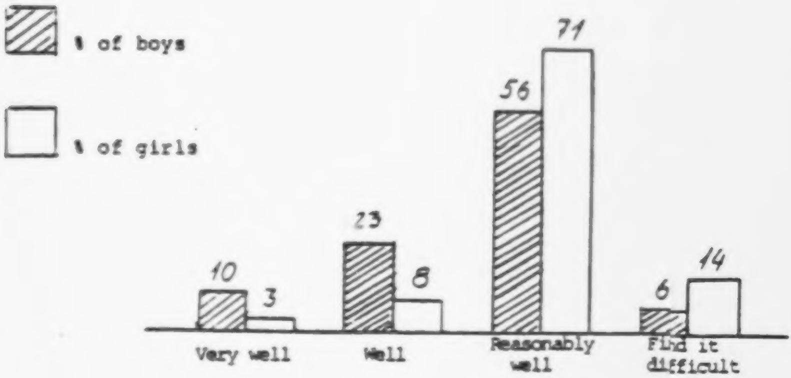
Questions about Attitudes

I have also asked the pupils about their expectations to their future success in physics/chemistry.

I found that girls had a low degree of self-esteem expecting to find the subject of physics/chemistry difficult.

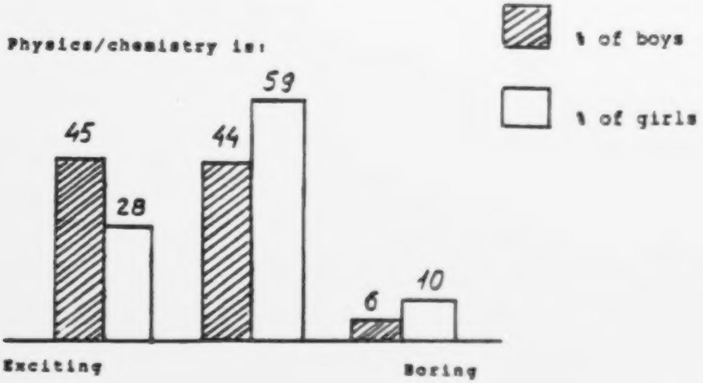
Figure 1.:

How do you think you will do in physics/chemistry?



The girls proved to be less interested in physics/chemistry than the boys:

Figure 2.:



Two questions are related to their work done in the physics/chemistry lessons:

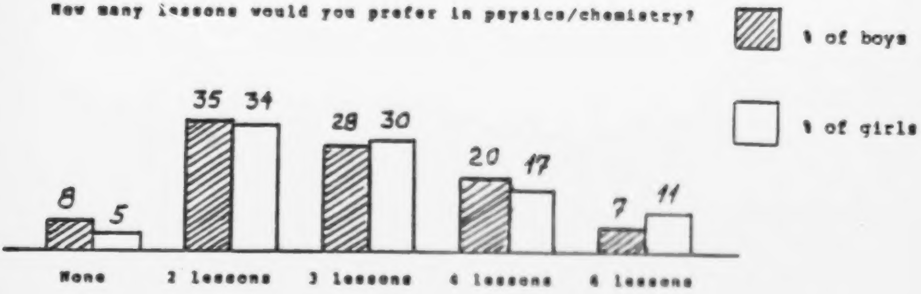
One is about how they would prefer to organize their work, i. e. self-studies, pupils' experiments, teachers' demonstrations - teachers' information - group experiments (table 12).

Girls' and boys' answers differ only slightly. The girls have a slightly higher preference to group work than boys, and a small majority of boys give first priority to own experiments.

The other is about what would be the optimal learning situation for themselves (table 13).

As appears from figure 3 boys´ and girls´ wishes for lessons were almost the same.

Fig. 3.



Future Plans

I have collected my data from the 11 schools in Hvidovre, and I expect to be able to confirm the results already found in corresponding British and Norwegian studies of the differences in childrens´ experience and attitudes to physics/chemistry.

My principle purpose, however, was to make it possible to draw some conclusions in order that the teaching in the subject could be improved.

I think that the psysics/chemistry teaching should be introduced at an earlier stage so that the girls can enter their puberty with an unprejudiced mind. One of the advantages would be that via their play in school the girls will be able to gain the experience that might not be possible in their time off.

I will strive to change the way and the contents of the teaching in order to create a coherence between on one side the psysical and chemical subjects and on the other the pupils´ everyday lives - both those of the boys and of the girls.

It is important to plan the teaching in a way that it is possible to counteract the higher degree of uncertainty found with the girls. Therefore, follow-up of tests and acceptance of results are important factors to the girls. This is particularly essential from the very start of the teaching so that the girls´ self-assurance is furthered.

It is necessary, however, that the teacher is aware of the difficulties that the girls feel they have in this subject.

The problems of girls´ attitudes to science have been advanced on several occasions, for instance at the GASAT Conferences. So it is very important that in order to overcome the problems, programmes of action are now prepared - but if changes are to take place in the schools,it is important that also the ´ordinary´ teachers are made aware of the problems which those who are interested long ago have found to be obvious.

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Institut of Physics, University of Oslo
P.O.Box, Blindern, Oslo 3

Girls and Science and Technology
Constributions to the third GASAT conference
Chelsea College, University of London
Centre for Science and Mathematics Education
Bridges Place London SW6 4HR

Table 1.

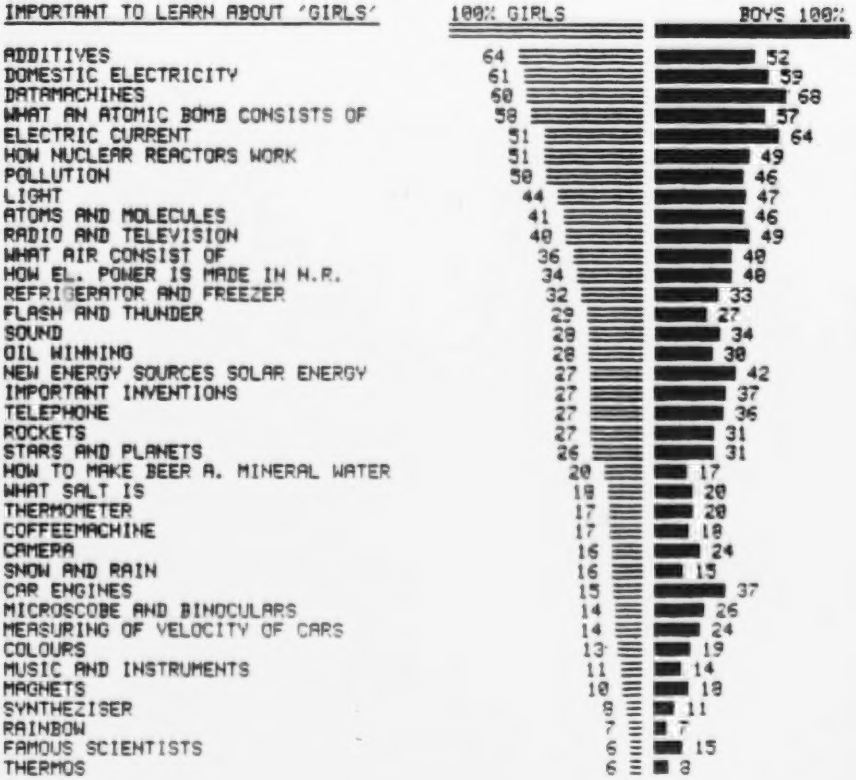
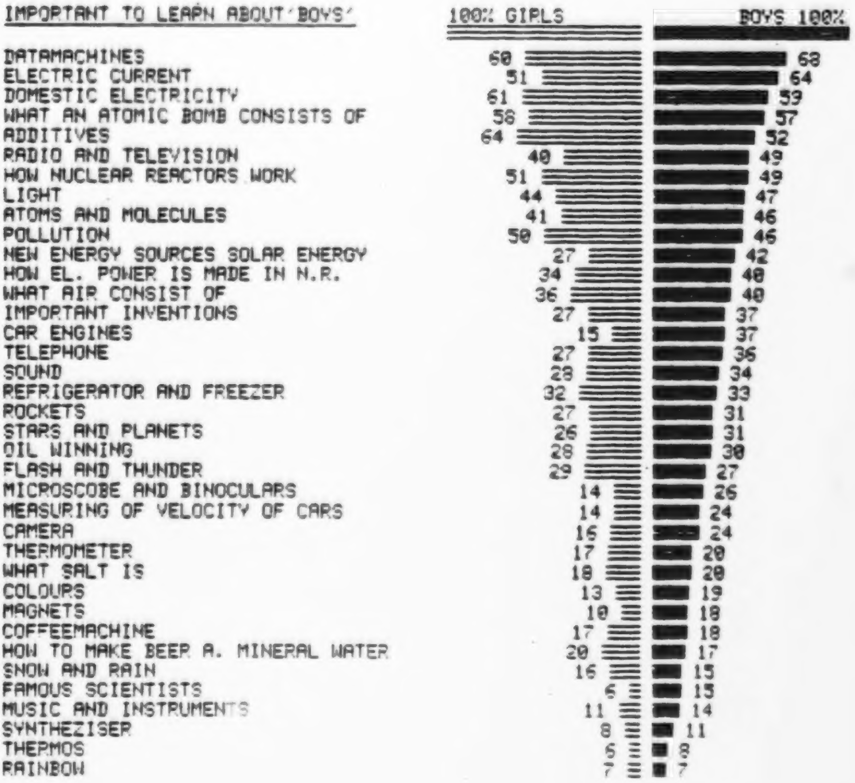

IMPORTANT TO LEARN ABOUT 'GIRLS'
100% GIRLS
BOYS 100%
ADDITIVES 64 52
DOMESTIC ELECTRICITY 61 59
DATAMACHINES 60 68
WHAT AN ATOMIC BOMB CONSISTS OF 58 57
ELECTRIC CURRENT 51 64
HOW NUCLEAR REACTORS WORK 51 49
POLLUTION 50 46
LIGHT 44 47
ATOMS AND MOLECULES 41 46
RADIO AND TELEVISION 40 49
WHAT AIR CONSIST OF 36 40
HOW EL. POWER IS MADE IN N.R. 34 40
REFRIGERATOR AND FREEZER 32 33
FLASH AND THUNDER 29 27
SOUND 28 34
OIL WINNING 28 30
NEW ENERGY SOURCES SOLAR ENERGY 27 42
IMPORTANT INVENTIONS 27 37
TELEPHONE 27 36
ROCKETS 27 31
STARS AND PLANETS 26 31
HOW TO MAKE BEER A. MINERAL WATER 20 17
WHAT SALT IS 18 20
THERMOMETER 17 20
COFFEEMACHINE 17 18
CAMERA 16 24
SNOW AND RAIN 16 15
CAR ENGINES 15 37
MICROSCOBE AND BINOCULARS 14 26
MEASURING OF VELOCITY OF CARS 14 24
COLOURS 13 19
MUSIC AND INSTRUMENTS 11 14
MAGNETS 10 18
SYNTHEZISER 8 11
RAINBOW 7 7
FAMOUS SCIENTISTS 6 15
THERMOS 6 8

Table 2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100% GIRLS
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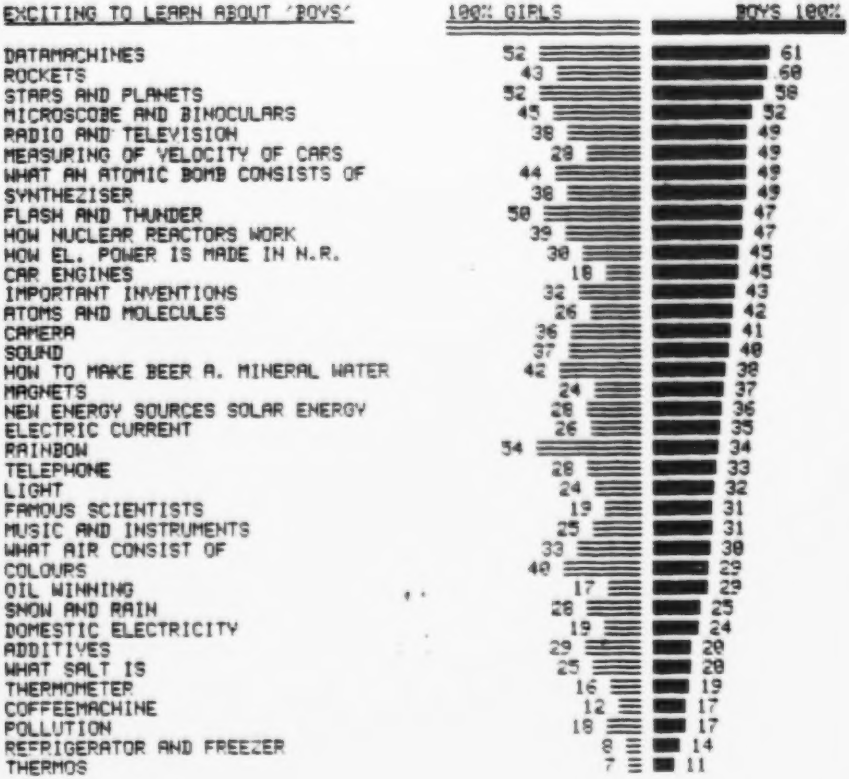
SNOW AND RAIN 16 15
FAMOUS SCIENTISTS 6 15
MUSIC AND INSTRUMENTS 11 14
SYNTHEZISER 8 11
THERMOS 6 8
RAINBOW 7 7

Table 3.

IMPORTANT 'GIRLS-BOYS'	100% GIRLS	BOYS 100%
ADDITIVES	64	52
POLLUTION	50	46
HOW TO MAKE BEER A. MINERAL WATER	20	17
DOMESTIC ELECTRICITY	61	59
HOW NUCLEAR REACTORS WORK	51	49
FLASH AND THUNDER	29	27
WHAT AN ATOMIC BOMB CONSISTS OF	58	57
SNOW AND RAIN	16	15
RAINBOW	7	7
REFRIGERATOR AND FREEZER	32	33
COFFEEMACHINE	17	18
OIL WINNING	28	30
WHAT SALT IS	18	20
THERMOS	5	8
LIGHT	44	47
THERMOMETER	17	20
MUSIC AND INSTRUMENTS	11	14
SYNTHEZISER	8	11
WHAT AIR CONSIST OF	36	40
ROCKETS	27	31
ATOMS AND MOLECULES	41	46
STARS AND PLANETS	26	31
HOW EL. POWER IS MADE IN N.R.	34	40
SOUND	28	34
COLOURS	13	19
DATAMACHINES	60	68
CAMERA	16	24
MAGNETS	10	18
RADIO AND TELEVISION	40	49
TELEPHONE	27	36
FAMOUS SCIENTISTS	6	15
IMPORTANT INVENTIONS	27	37
MEASURING OF VELOCITY OF CARS	14	24
MICROSCOBE AND BINOCULARS	14	26
ELECTRIC CURRENT	51	64
NEW ENERGY SOURCES SOLAR ENERGY	27	42
CAR ENGINES	15	37

Table 4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BOYS 100%
DATAMACHINES 52 61
ROCKETS 43 60
STARS AND PLANETS 52 58
MICROSCOBE AND BINOCULARS 45 52
RADIO AND TELEVISION 38 49
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RAINBOW 54 34
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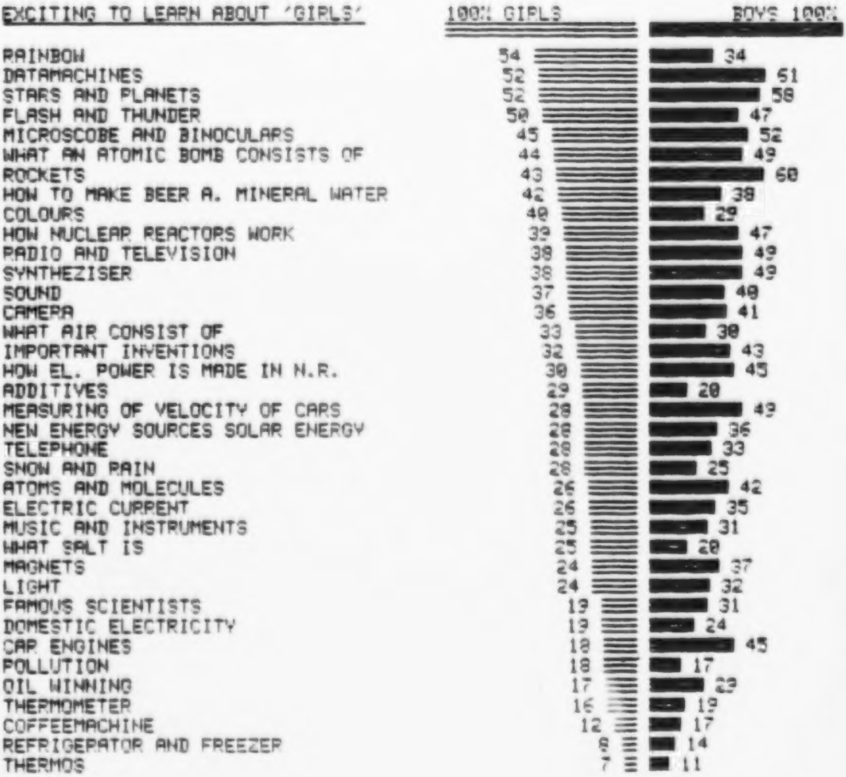
REFRIGERATOR AND FREEZER 8 14
THERMOS 7 11

Table 5.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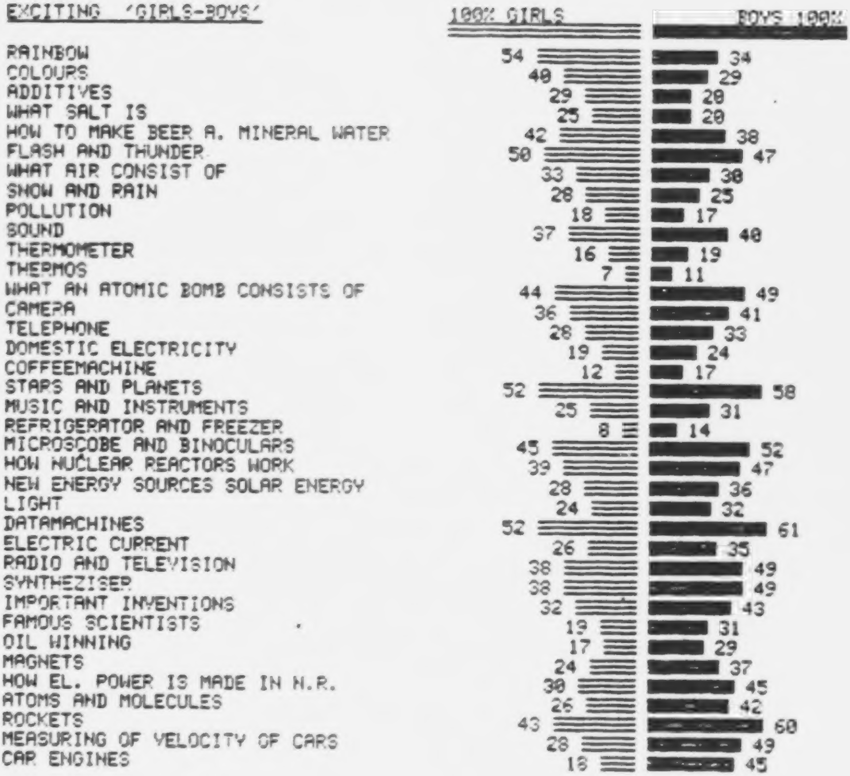


EXCITING 'GIRLS-BOYS'	100% GIRLS	BOYS 100%
RAINBOW	54	34
COLOURS	40	29
ADDITIVES	29	20
WHAT SALT IS	25	20
HOW TO MAKE BEER A. MINERAL WATER	42	38
FLASH AND THUNDER	50	47
WHAT AIR CONSIST OF	33	30
SNOW AND RAIN	28	25
POLLUTION	18	17
SOUND	37	40
THERMOMETER	16	19
THERMOS	7	11
WHAT AN ATOMIC BOMB CONSISTS OF	44	49
CAMERA	36	41
TELEPHONE	28	33
DOMESTIC ELECTRICITY	19	24
COFFEEMACHINE	12	17
STARS AND PLANETS	52	58
MUSIC AND INSTRUMENTS	25	31
REFRIGERATOR AND FREEZER	8	14
MICROSÇOBE AND BINOCULARS	45	52
HOW NUĆLEAR REACTORS WORK	39	47
NEW ENERGY SOURCES SOLAR ENERGY	28	36
LIGHT	24	32
DATAMACHINES	52	61
ELECTRIC CURRENT	26	35
RADIO AND TELEVISION	38	49
SYNTHEZISER	38	49
IMPORTANT INVENTIONS	32	43
FAMOUS SCIENTISTS	19	31
OIL WINNING	17	29
MAGNETS	24	37
HOW EL. POWER IS MADE IN N.R.	30	45
ATOMS AND MOLECULES	26	42
ROCKETS	43	60
MEASURING OF VELOCITY OF CARS	28	49
CAR ENGINES	18	45

TABLE 7

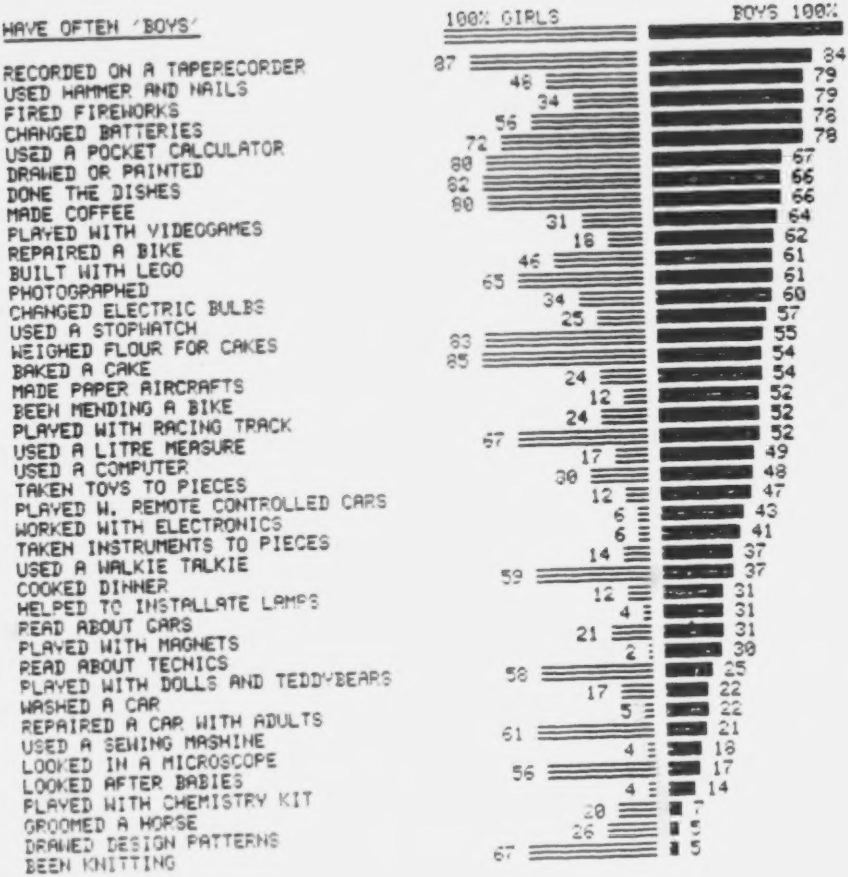

HAVE OFTEN 'BOYS'
100% GIRLS
BOYS 100%
RECORDED ON A TAPERECORDER 87 84
USED HAMMER AND NAILS 48 79
FIRED FIREWORKS 34 79
CHANGED BATTERIES 56 78
USED A POCKET CALCULATOR 72 78
DRAWED OR PAINTED 80 67
DONE THE DISHES 82 66
MADE COFFEE 80 66
PLAYED WITH VIDEOGAMES 31 64
REPAIRED A BIKE 18 62
BUILT WITH LEGO 46 61
PHOTOGRAPHED 65 61
CHANGED ELECTRIC BULBS 34 60
USED A STOPWATCH 25 57
WEIGHED FLOUR FOR CAKES 83 55
BAKED A CAKE 85 54
MADE PAPER AIRCRAFTS 24 54
BEEN MENDING A BIKE 12 52
PLAYED WITH RACING TRACK 24 52
USED A LITRE MEASURE 67 52
USED A COMPUTER 17 49
TAKEN TOYS TO PIECES 30 48
PLAYED W. REMOTE CONTROLLED CARS 12 47
WORKED WITH ELECTRONICS 6 43
TAKEN INSTRUMENTS TO PIECES 6 41
USED A WALKIE TALKIE 14 37
COOKED DINNER 59 37
HELPED TO INSTALLATE LAMPS 12 31
READ ABOUT CARS 4 31
PLAYED WITH MAGNETS 21 31
READ ABOUT TECHICS 2 30
PLAYED WITH DOLLS AND TEDDYBEARS 58 25
WASHED A CAR 17 22
REPAIRED A CAR WITH ADULTS 5 22
USED A SEWING MASHINE 61 21
LOOKED IN A MICROSCOPE 4 18
LOOKED AFTER BABIES 56 17
PLAYED WITH CHEMISTRY KIT 4 14
GROOMED A HORSE 20 7
DRAWED DESIGN PATTERNS 26 5
BEEN KNITTING 67 5

TABLE 8

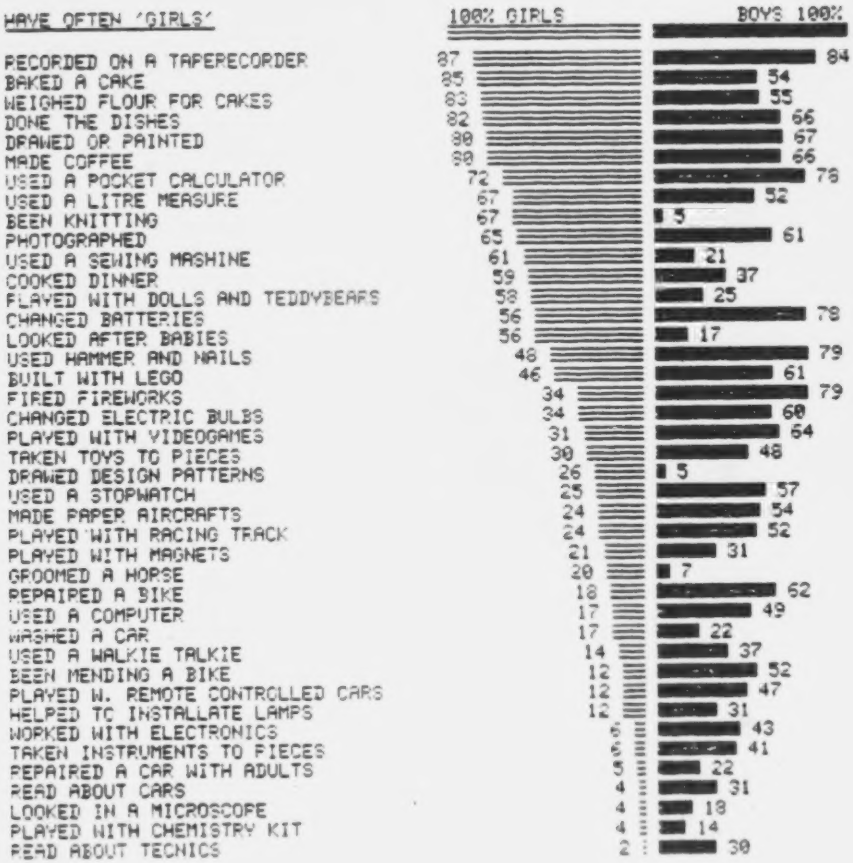

HAVE OFTEN 'GIRLS'
100% GIRLS
BOYS 100%
RECORDED ON A TAPERECORDER 87 84
BAKED A CAKE 85 54
WEIGHED FLOUR FOR CAKES 83 55
DONE THE DISHES 82 66
DRAWED OR PAINTED 80 67
MADE COFFEE 80 66
USED A POCKET CALCULATOR 72 78
USED A LITRE MEASURE 67 52
BEEN KNITTING 67 5
PHOTOGRAPHED 65 61
USED A SEWING MASHINE 61 21
COOKED DINNER 59 37
PLAYED WITH DOLLS AND TEDDYBEARS 58 25
CHANGED BATTERIES 56 78
LOOKED AFTER BABIES 56 17
USED HAMMER AND NAILS 48 79
BUILT WITH LEGO 46 61
FIRED FIREWORKS 34 79
CHANGED ELECTRIC BULBS 34 60
PLAYED WITH VIDEOGAMES 31 64
TAKEN TOYS TO PIECES 30 48
DRAWED DESIGN PATTERNS 26 5
USED A STOPWATCH 25 57
MADE PAPER AIRCRAFTS 24 54
PLAYED WITH RACING TRACK 24 52
PLAYED WITH MAGNETS 21 31
GROOMED A HORSE 20 7
REPAIRED A BIKE 18 62
USED A COMPUTER 17 49
WASHED A CAR 17 22
USED A WALKIE TALKIE 14 37
BEEN MENDING A BIKE 12 52
PLAYED W. REMOTE CONTROLLED CARS 12 47
HELPED TO INSTALLATE LAMPS 12 31
WORKED WITH ELECTRONICS 6 43
TAKEN INSTRUMENTS TO PIECES 6 41
REPAIRED A CAR WITH ADULTS 5 22
READ ABOUT CARS 4 31
LOOKED IN A MICROSCOPE 4 18
PLAYED WITH CHEMISTRY KIT 4 14
READ ABOUT TECNICS 2 30

TABLE 9

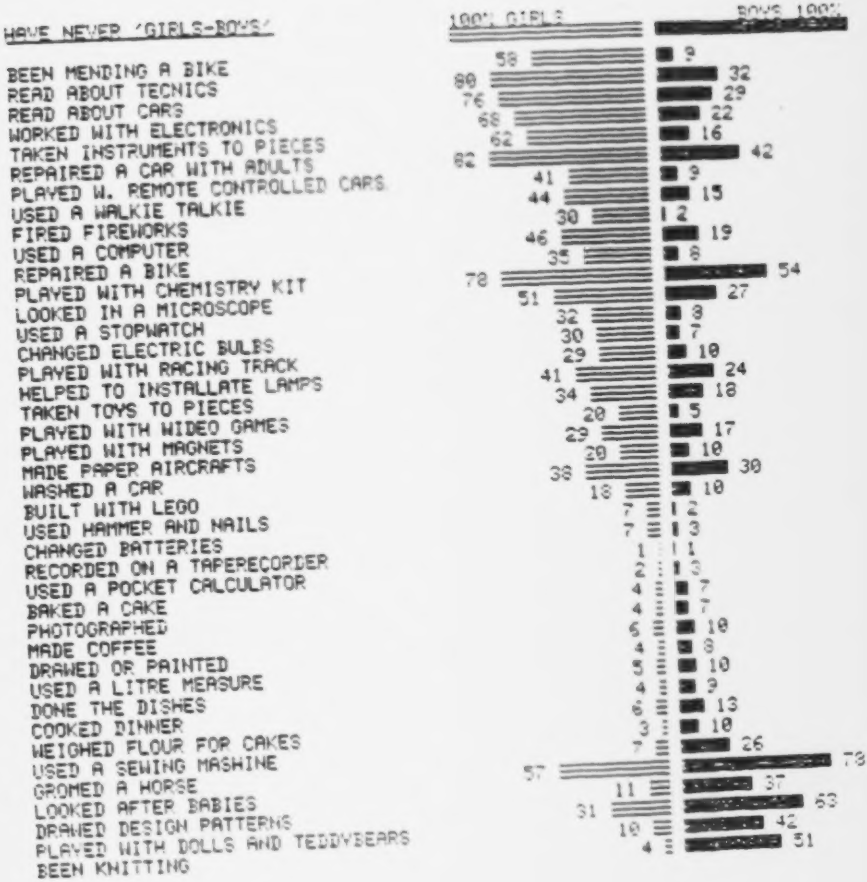
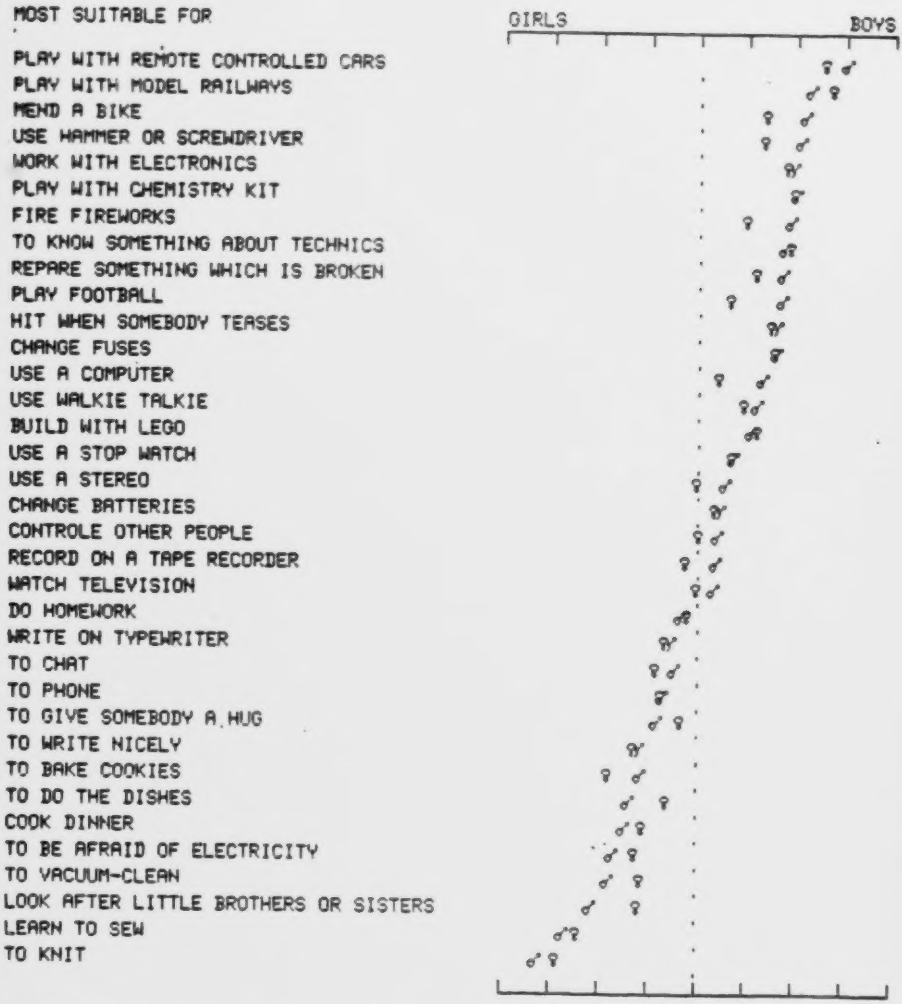

HAVE NEVER 'GIRLS-BOYS'
100% GIRLS
BOYS 100%
BEEN MENDING A BIKE 58 9
READ ABOUT TECNICS 80 32
READ ABOUT CARS 76 29
WORKED WITH ELECTRONICS 68 22
TAKEN INSTRUMENTS TO PIECES 62 16
REPAIRED A CAR WITH ADULTS 82 42
PLAYED W. REMOTE CONTROLLED CARS 41 9
USED A WALKIE TALKIE 44 15
FIRED FIREWORKS 30 2
USED A COMPUTER 46 19
REPAIRED A BIKE 35 8
PLAYED WITH CHEMISTRY KIT 78 54
LOOKED IN A MICROSCOPE 51 27
USED A STOPWATCH 32 8
CHANGED ELECTRIC BULBS 30 7
PLAYED WITH RACING TRACK 29 10
HELPED TO INSTALLATE LAMPS 41 24
TAKEN TOYS TO PIECES 34 18
PLAYED WITH WIDEO GAMES 20 5
PLAYED WITH MAGNETS 29 17
MADE PAPER AIRCRAFTS 20 10
WASHED A CAR 38 30
BUILT WITH LEGO 18 10
USED HAMMER AND NAILS 7 2
CHANGED BATTERIES 7 3
RECORDED ON A TAPERECORDER 1 1
USED A POCKET CALCULATOR 2 3
BAKED A CAKE 4 7
PHOTOGRAPHED 4 7
MADE COFFEE 6 10
DRAWED OR PAINTED 4 8
USED A LITRE MEASURE 5 10
DONE THE DISHES 4 9
COOKED DINNER 6 13
WEIGHED FLOUR FOR CAKES 3 10
USED A SEWING MASHINE 7 26
GROMED A HORSE 57 78
LOOKED AFTER BABIES 11 37
DRAWED DESIGN PATTERNS 31 63
PLAYED WITH DOLLS AND TEDDYBEARS 10 42
BEEN KNITTING 4 51

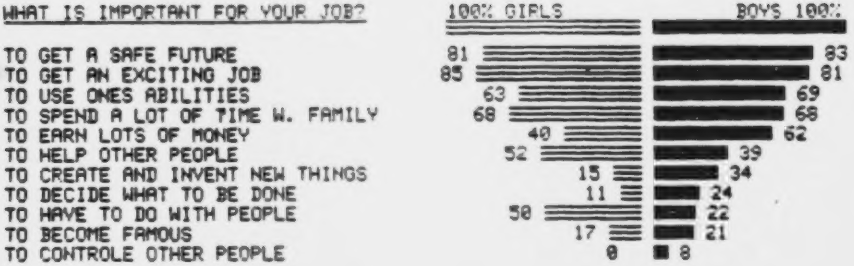
Table 10.



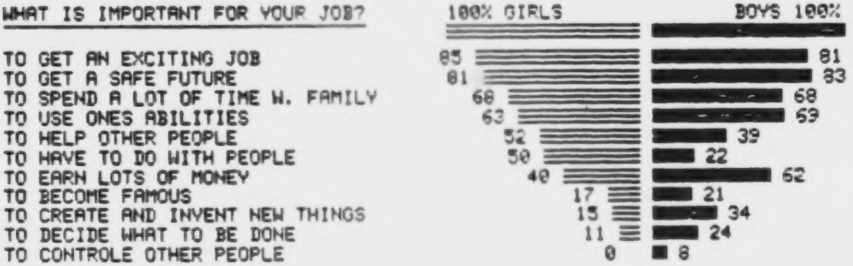
The figure shows the difference between those activities that girls and boys have indicated as"suitable for girls"and suitable for boys"

Table 11

A)


WHAT IS IMPORTANT FOR YOUR JOB?
100% GIRLS
BOYS 100%
TO GET A SAFE FUTURE 81 83
TO GET AN EXCITING JOB 85 81
TO USE ONES ABILITIES 63 69
TO SPEND A LOT OF TIME W. FAMILY 68 68
TO EARN LOTS OF MONEY 40 62
TO HELP OTHER PEOPLE 52 39
TO CREATE AND INVENT NEW THINGS 15 34
TO DECIDE WHAT TO BE DONE 11 24
TO HAVE TO DO WITH PEOPLE 50 22
TO BECOME FAMOUS 17 21
TO CONTROLE OTHER PEOPLE 0 8

B)


WHAT IS IMPORTANT FOR YOUR JOB?
100% GIRLS
BOYS 100%
TO GET AN EXCITING JOB 85 81
TO GET A SAFE FUTURE 81 83
TO SPEND A LOT OF TIME W. FAMILY 68 68
TO USE ONES ABILITIES 63 69
TO HELP OTHER PEOPLE 52 39
TO HAVE TO DO WITH PEOPLE 50 22
TO EARN LOTS OF MONEY 40 62
TO BECOME FAMOUS 17 21
TO CREATE AND INVENT NEW THINGS 15 34
TO DECIDE WHAT TO BE DONE 11 24
TO CONTROLE OTHER PEOPLE 0 8

C)

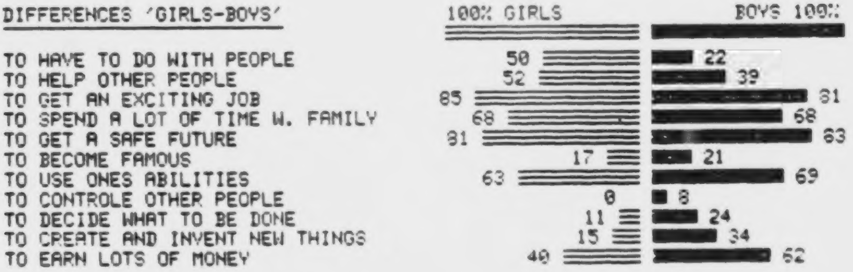
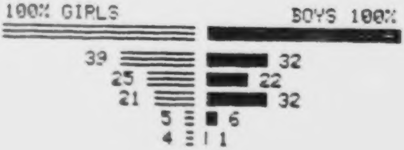

DIFFERENCES 'GIRLS-BOYS'
100% GIRLS
BOYS 100%
TO HAVE TO DO WITH PEOPLE 50 22
TO HELP OTHER PEOPLE 52 39
TO GET AN EXCITING JOB 85 81
TO SPEND A LOT OF TIME W. FAMILY 68 68
TO GET A SAFE FUTURE 81 83
TO BECOME FAMOUS 17 21
TO USE ONES ABILITIES 63 69
TO CONTROLE OTHER PEOPLE 0 8
TO DECIDE WHAT TO BE DONE 11 24
TO CREATE AND INVENT NEW THINGS 15 34
TO EARN LOTS OF MONEY 40 62

TABLE 12

HOW WOULD YOU PREFERE TO ORGANIZE YOUR WORK?

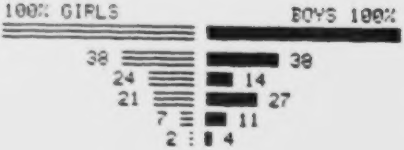
TEACHERS' DEMONSTRATIONS

3
1
2
4
5



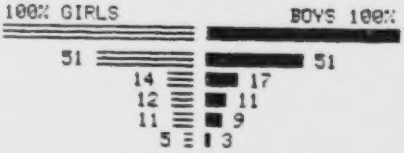
GROUP EXPERIMENTS

2
1
3
4
5



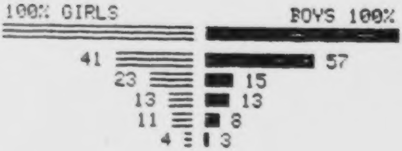
TEACHERS' INFORMATION

4
3
5
2
1



PUPILS' EXPERIMENTS

1
2
3
4
5



SELF-STUDIES

5
4
3
2
1

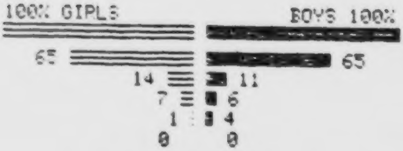


TABLE 13

WHAT IS YOUR OPTIMAL LEARNING SITUATION?

TEACHERS' DEMONSTRATIONS	100% GIRLS	BOYS 100%
3	34	26
2	24	34
1	15	15
4	12	31
5	6	5

TEACHERS' INFORMATION	100% GIRLS	BOYS 100%
4	36	31
3	18	16
2	16	15
1	11	18
5	11	10

SELF-STUDIES	100% GIRLS	BOYS 100%
5	52	43
4	18	19
2	9	10
3	8	13
1	3	3

PUPILS' EXPERIMENTS	100% GIRLS	BOYS 100%
1	46	45
2	16	14
3	13	13
5	9	11
4	7	9

GROUP EXPERIMENTS	100% GIRLS	BOYS 100%
2	28	21
3	20	23
1	18	11
4	14	18
5	10	17

SCIENCE EDUCATION AND THE FUTURE OF DENMARK

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Emdrupvej 115 B, DK-2400 Copenhagen NV, Denmark

Introduction

In a country like Denmark without spectacular natural resources or outstanding potential for agriculture, it is necessary for industry to be highly competitive, if the standard of living (including national security, foreign aid programmes, etc.) shall be preserved. So far, this has been possible for Denmark in spite of the fact that the expenditures for scientific research and development have been far below those of comparable countries such as Sweden, West Germany, or the U.K.

Unfortunately, this situation may not last long. In order for Danish industry to compete on world markets in the future, a new industrial strategy seems to be necessary, a strategy which gives high priority to the development of new, advanced products. This need for a much more determined effort in both basic and industrial research and development has been evident for some years, but the results are not impressive at all. One important reason is that the investments in scientific research and development still are very low in Denmark. But an equally important, but often poorly recognized reason may be found in the Danish educational system.

Science in the Danish educational system

The Danish educational system is almost unique internationally because of the low priority given in schools to some of the basic natural sciences, for example chemistry, a key area for Danish industry and a vital field in connection with decisions on e.g. energy and environmental policy. Chemistry is taught in Danish schools in year 8 and 9, and many students also take chemistry in year 10 and 11. Still, on the average only 1.3 % of the total time in schools is used for this important subject. The total effort in natural sciences in Danish schools in general is also below that of other comparable countries (Table 1). On the other hand, in Danish schools more time is spent on mathematics than in many other countries (Table 2). The substantial effort in mathematics is an obvious advantage e.g. for first year science students at Danish universities, who will often be able to use science textbooks written for a higher level in other countries. However, mathematics alone does not provide a sufficient background for a life in a high technological society, and it does not necessarily motivate students to choose careers in science and technology. Nor does a recent interest in informatics in Danish schools solve many of the problems. Informatics is a very useful tool, but without a basic knowledge within a field - biology, chemistry, physics, energeering - it will be of limited value.

Why teach science and technology?

Why do we, or why should we teach natural sciences at all in Danish schools? For several reasons:

1. The natural sciences are part of our culture and has changed our way of life drastically during the last century.

2. Any citizen in an industrialized democracy today must take part in important decisions on environment, energy, industrial and agricultural policies etc., all of which require a solid background in natural sciences. Our politicians often tend to make decisions which they believe are right politically. Only if the electorate has the necessary knowledge, the "politically right" decisions will also be the "scientifically right" ones.

SCIENCE IN NORDIC SCHOOLS

NUMBER OF PERIODS (45 MIN.) PER WEEK IN BIOLOGY, CHEMISTRY, AND PHYSICS.

(THE SECOND COLUMN INDICATES THE PERCENTAGE OF THE TOTAL NUMBER OF PERIODS).

YEAR	DENMARK		FINLAND		NORWAY	
	PERIODS	%	PERIODS	%	PERIODS	%
1	0	0	3[b]	14	0	0
2	0	0	2[b]	10	1	6
3	1	4	4[c]	16	1	5
4	1	4	4[c]	15	2	8
5	1	4	3[c]	12	2	8
6	2	7	3[c]	12	3	11
7	4	13	4[c]	13	3	10
8	2	7	4[c]	13	3	10
9	2	7	6[c]	20	3	10
10	3[a]	10	4[a]	13	5	17
11	3[a]	10	3[a]	9	3[a]	10
12	2[a]	7	1[a]	5	2[a]	8
AVERAGE	1.8	5%	3.4	13%	2.3	9%

a: AVERAGE FOR ALL STUDENTS

b: ENVIRONMENTAL STUDIES INCLUDED

c: GEOGRAPHY INCLUDED

TABLE 1.

Note also the difference in the distribution of natural science education in the three countries: In Denmark and Norway these subjects appear mostly in the higher grades, while they have a very high weight in the lower grades in Finland. This might possibly result in a more positive attitude towards science and technology among girls in Finland than in the other two countries.

SCIENCE IN NORDIC SCHOOLS

NUMBER OF PERIODS (45 MIN.) PER WEEK IN BIOLOGY, CHEMISTRY, PHYSICS, AND MATHEMATICS.

(THE SECOND COLUMN INDICATES THE PERCENTAGE OF THE TOTAL NUMBER OF PERIODS).

YEAR	DENMARK		FINLAND		NORWAY	
	PERIODS	%	PERIODS	%	PERIODS	%
1	4	22	6[b]	29	3	19
2	4	20	6[b]	29	4	25
3	5	23	7[c]	28	5	26
4	5	20	7[c]	27	6	24
5	5	19	7[c]	27	5	20
6	6	21	7[c]	27	6	21
7	8	27	7[c]	23	7	23
8	6	20	7[c]	23	7	23
9	6	20	10[c]	33	6	21
10	7[a]	23	8[a]	23	10[a]	33
11	7[a]	23	6[a]	18	6[a]	20
12	8[a]	27	4[a]	17	5[a]	16
AVERAGE	5.9	22%	6.8	25%	5.8	23%

a: AVERAGE FOR ALL STUDENTS

b: ENVIRONMENTAL STUDIES INCLUDED

c: GEOGRAPHY INCLUDED

TABLE 2.

3. Finally, the need for a work force with much higher qualifications in science and technology than that of the present one is becoming obvious (Figure 1). These new requirements have already had some effect - the unemployment among engineers and natural scientists has been lower than in essentially all other fields in recent years - and will have even more impact in the near future, especially if an industrial upswing is on its way. One particular aspect of the present conditions is that girls seem to be very poorly motivated for careers in science and technology, which could otherwise help to provide true equality between the sexes and reduce unemployment among women.

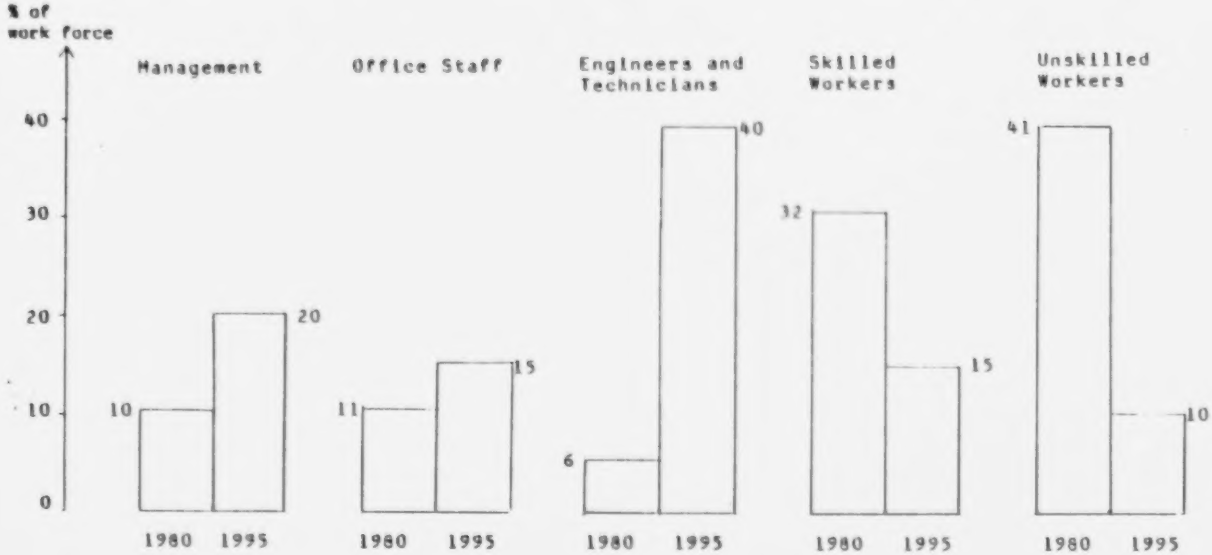
Denmark has very strong traditions in adult education. Are any efforts being made in this field to compensate for the poor performance in the school system? Unfortunately not; the interest in adult education seems to be directed towards completely different areas. Even subjects like astrology or healing are frequently given higher priority than physics and chemistry.

With this background it is difficult to imagine a smooth transformation of the present Denmark into a high-technology society. Therefore, the very modest interest for science education in Denmark among politicians, industrial leaders, and particularly the media can only be explained by a lack of understanding of the impact science education in schools may have on the future society.

The persons who will join the work force ten years from now and who will have to fulfill requirements like those indicated in Fig. 1 are already on their way through the Danish school system. It may already be too late to make changes in this system, which will help these young people become well-informed (and satisfied) citizens in a high-technology democracy and help them choose careers which will be of mutual benefit for themselves and society.

Hopefully, political and industrial leaders as well as the media will soon realize the urgency of the situation and

Figure 1: EXPECTED TRENDS IN THE COMPOSITION OF THE INDUSTRIAL WORK FORCE.



Source: FAST B. 2, ref. 5 and "Jernets Fremtid", Jernets Arbejdsgiverforening, Copenhagen 1983.
The figures are predictions for a British production industry.

join forces with the professional societies for the scientific and technological areas in order to secure that the younger generations are more adequately prepared for those future requirements which we can now predict reasonably well. If not, the future of the Danish society looks black.

TEACHING ENERGY AND MECHANICS IN GRADE 8 IN DENMARK. WHICH TOPICS?

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Introduction

In 1975 a new syllabus for physics and chemistry in the Danish comprehensive school (lower secondary school) was introduced.

In the old syllabus much attention was paid to everyday equipment. It was stressed that the teacher should teach "the light bulb, the electric heater, the iron (for ironing clothes), the doorbell, the telegraph, the telephone, AC- and DC-motors" and so on.

In the new syllabus the main emphasis was placed on basic physical concepts and laws plus "THE scientific method".

The Present Physics Syllabus for Grade 8

One of the basic physical concepts being energy and some of the basic physical laws being Newton's laws it was decided that all children in the Danish comprehensive school should be taught mechanics - including Newton's laws and mechanical energy - in grade 8.

The authors of the textbooks have chosen to focus the presentation of Newtonian mechanics on linear motion. When doing so, it is possible to measure and calculate the magnitude of accelerations in different laboratory situations. The key-point is to "prove" Newton's 2nd law which, however, is scarcely used on any problem from everyday world outside of the classroom. Whereas the teaching of electricity and structure of matter in grade 7 to a large extent is based on the pupils' own experiments in the laboratory, most of the experiments in Newtonian mechanics in grade 8 are demonstrations performed by the teacher, and the ticker-tape-timer and roller-skate-trolleys are used quite frequently. The teachers as well as the children get quite bored. For a naive, not very carefully listening pupil it might seem as if the teacher is doing almost the same experiment again and again and again.

The teachers, of course, are not happy about the situation. Phrases like "the ticker-tape-timer psychosis" are used frequently in the discussions among physics teachers and the teachers ask for changes in the syllabus.

Good reasons for a change are, that the pupils do not grasp very much of the physical ideas and do not think that those ideas are of any use outside school. It might be added that several teachers think, too, that Newtonian mechanics has no relation to situations in everyday life: "Newton's 2nd law is valid only when there is no friction and no air resistance". Once a teacher asked me: Can you point out any situation in real life where Newton's 2nd law is useful?

Another example of an unsatisfactory outcome of the teaching concerns the concept "acceleration". Before entering grade 8 the pupils probably have some "correct" and meaningful content in this physical concept. Acceleration is something you might feel in your body when sitting in a car. It has to do with speeding up of motorbikes etc. According to the teachers, however, this content is almost completely washed away by the quite formal treatment, the calculations using the most peculiar unit m/s^2 etc.

In the treatment of energy in grade 8 there are no similar difficulties. Generally the concepts of kinetic and potential energy are easily manageable by the pupils (and teachers). There are no extensive calculations in the books as far as "energy" is concerned. You might, however, ask whether the connection between the "clean" laboratory experiments and the energy problems in society is sufficiently stressed in the physics course.

What are the most relevant physics concepts for those children who will not attend physics courses after grade 9? Perhaps "potential energy" and "kinetic energy" are less important concepts than "renewable energy" (energy from sun, wind etc.) and "stored energy" (coal, oil, natural gas).

In-Service-Courses for Physics Teachers

At the Physics Department of the Royal Danish School of Educational Studies one of our jobs is to maintain a good contact to the folk-school to help the teachers to cope with some of their problems. We make educational research, we develop new materials (written materials as well as laboratory equipment) and we give in-service-courses for the teachers.

The last four years we have run courses for teachers who have been forced (more or less) to take up teaching physics at school without having more than a superficial knowledge of physics. Such courses have been utilized as a test-lab for new ideas concerning the teaching af mechanics by my collegue Hans Lütken and myself.

For the topic "energy" there seems to be no major difficulties in giving a presentation where physics, every day life and problems in society are connected in such a way that the teachers find it exciting, relevant and useful.

The picture is different when Newton's laws are considered. It has been quite a challenge for us to try to make the teachers feel Newtonian mechanics relevant and to give a presentation so that the physical content and not the formalism is stressed.

Last winter (1983-84) we tried that for the first time. In May 1984, at the end of the course, we gave the teachers a multiple-choice-test, the results of which clearly revealed that "prescientific" or "everyday" concepts and ideas ("frameworks") had survived quite well. E.g. a force is not something acting on a body from outside, but something a body "has". It is an intrinsic property of the body. It is worthwhile to remember the findings of the PLON-group in Holland. The pupils obtained a much better understanding of the unit "Bridges" when emphasis was changed from discussing "pushes" and "pulls" on the different parts of a bridge to discussing "stresses" and "tensions" inside the different parts.

The results of the test were by no means more shocking or disappointing than the results of numerous other tests on mechanical problems from every day life, performed recently in several countries among pupils of primary school, pupils of secondary school, and even university students.

When designing our course we had, however, tried to take the existence of "prescientific frameworks" into account e.g. by telling about old Greek and medieval theories for motion and by showing the insufficiency of such theories. Faced in a test with a "non-textbook-problem" quite a large fraction of the teachers (our students), however, used a pre-Newtonian way of reasoning.

At the GIREP conference in Utrecht August 1984 "The Many Faces of Teaching and Learning Mechanics" I hoped to get some ready-to-use-solutions to overcome the problems. There seems, however, to be no such simple solutions.

At our course this winter Hans Lütken and I have been stressing the qualitative aspects of Newtonian mechanics, almost completely avoiding calculations.

Then other problems arise. As one of our students said a few days ago: It is simple logic that it is more difficult to bring a heavy object into motion than a light object.

Although I do not like the way he used the word logic, I understand what he is trying to say. Are we simply trying to tell some straightforward and not too exciting things in a complicated and somewhat boring way?

At the moment one of Hans Lütken's and my own conclusions of our work for the last two years is that we have to concentrate the presentation of Newtonian mechanics on some important applications so that the pupils obtain new insight which they find thrilling and exciting and perhaps even useful in everyday life or so that the pupils solve problems which were insoluble to them before the course, and which they find worthwhile and useful to solve.

Another conclusion is that Newtonian mechanics should probably take up only a minor part of the curriculum for the comprehensive school. As stressed by other speakers at this conference physics has such strong relations to many aspects in the development of the society and the conditions of life for the individual as well as the life of mankind that more of our efforts should probably be concentrated on coping with that.

Reform of The Syllabus?

Recently there has been important political signals that perhaps time has come to change the physics syllabus in Denmark, one of the reasons being the concern of the "girls and physics" problem.

Maybe the problem, however, is not only "girls and physics" but "pupils and physics". Several parts of the present physics curriculum ask for a revision.

The reform of the syllabus in 1975 constituted an important step forward. Now time may have come for further improvement, and to that end this conference has provided some quite useful inspirations.

Reference:

The Many Faces of Teaching and Learning Mechanics
Proceedings of a Conference on Physics Education
Utrecht 20.-25. August 1984
Published by W.C.C. - Utrecht 1985.

EDUCATIONAL TRADITIONS IN DANISH SCHOOL-CHEMISTRY AND AN INFORMATION ABOUT DANISH EDUCATION ACTS DURING THE LAST 170 YEARS.

Svenn Wøjdemann,
Innovation Centre for General Education,
Islevgård alle 5, 2610 Rødovre, Denmark.

The majority of danish science teachers will deny that we have such traditions, but admit that we at present are building them up.

THE EDUCATION ACT OF 1814.

Denmark was the first country in the world to have a Primary Education Act that included a compulsory education. The Act was available in 1814, a time of political disturbances and economic decline for the country. Seven years before that, in 1807, the Danish Fleet had been captured by the British. The decline was fulfilled by a bankruptcy of the state in 1813, and in 1814 the loss of Norway that had been under the Danish Crown for hundreds of years. The Danish King was definitely not estimated among the princes of Europe, and if he shouldn't know, the missing invitation for the Vienna Congress in 1815 proved so. He managed to sqeeze through under cover, - being the Count of some inferior Danish island as well as King of Denmark. The latter he forgot to mention.

It looks like the time of depression gives a lift to the cultural life. During this period literature and painting are in full bloom, the so called 'Golden Age', and a Primary Act is created, an Act that almost outmatches the current one, for the part of its progressivity in pedagogical matters.

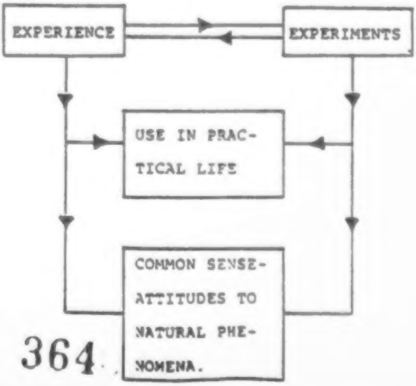
NATURAL EXPERIENCE.

All subjects concerning science were taught under the common denominator of 'Natural Experience' - in German language Naturkunde - , meaning that the pupil became versed in natural science. Natural experience included natural history, describing the living nature, and physics, describing the non-living nature. Physics and chemistry are not mentioned in the 1814-Act as terms or titles. Its relatively high number of lessons per week underlines the importance and high-ranking position given to Natural Experience. It was outnumbered only by three subjects, religious instruction, mother tongue and math.

The trend of to-day is that a subject called 'Natural Information' should be introduced. The subject resembles the Natural Experience from the 1814-Act in an up to date version. To me it seems that the name Natural Experience stands for a higher qualification than just Natural Information. But the intention might be that the range of qualifications is extended. The unified school system demands so.

The necessary abilities and experience for the teacher of Natural Experience is described in the 1814-Act,

'The teacher must possess a clear experience- and experimentbased knowledge of general laws, powers and effect of nature. His knowledge should be of senseful use in everyday life as well as to give him insight in occurring natural phenomena.'



MODEL 1814 - 2000

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.. NOTHING NEW UNDER THE SUN.

The Primary Education Act of 1814 was characterized by the humanity of its inventors. One school, part of the Count Reventlow's estate Christianssæde, the Count himself gave word to the object of his school:

'The mental strength of the children should be widened and elaborated in school. The development must be accomplished at a moderate speed and in a way that makes the children find it a joy going to school. Things that are hard to learn must be mixed with easier ones. Consider, that the use of senses should be prior to the use of the intellect in the beginning of school life. Remember, that constant variations in methods facilitate their attention.

School hours must be short so that the child does not get bored and between lessons the children should be allowed to outdoor activities in order to recreate mind and body. The short school hours are also important for the parents, who will let their kids go to school more frequently, if there is time left for the necessary help at home. '

Now, why did the children need Natural Experience? Here are some 1814-Act biddings:

1. Acknowledgement of phenomena in nature proves the omnipotence, wisdom and goodness of God.

2. Acquaintance with Natural Experience eliminates much bad superstition.

3. Acquaintance with Natural Experiments is useful to common people in their dayly work.

4. Acquaintance with Natural Experience transforms nature into a friendly residence to its inhabitants.

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THE MALE/FEMALE "PROBLEM".

The topic of to-day is the male/female problem. This problem was taken care of in the following way by the Copenhagen version of the Act. My quotation:

'What the girls need from Natural Experience, the teacher will pass on to them during the Natural History. The boys on the other hand ought to be especially taught in Natural Experience as well as in technology so that they in due time will perform their handwork in a non-mechanical way.

During the following 144 years no Act made an effort to strengthen the education of physics and chemistry. Especially the chemistry became a stepchild. Almost all countries having reached a certain level of culture had introduced chemistry as an independant subject in county schools, but in Denmark of all countries it was mistreated. Organic chemistry was subordinated Natural History, and the inorganic chemistry became part of physics. A study of old textbooks in physics reveals that chemistry was completely in the dark.

MEMORIES.

I was a pupil in county school under the 1937-Act. My personal memories concerning chemistry are confined to three experiences, that prevented me from repeating any of them:

a. A brave or reckless substitute dropped a rather big lump of sodium into a bowl of water. It exploded and luckily it damaged only the clothes of the closer placed pupils. Everybody was able to walk out with their sight unhurt.

b. The teacher assigned to the subject intended to produce powder, and so he crushed potassium chlorate in a mortar. Of course it went apart with a proper bang.

c. I gained a detension hour because I was not able to mention the nineteen elements by heart. I remember they were placed in a footnote. Since then I made it my habit to read the footnotes more carefully than the proper text.

A coherent education in chemistry has not been received either by me or by my equals in age as far as memory goes.

This state of the subject was totally changed with the 1958-Act even if chemistry still wasn't raised to become a subject on its own.

LESSONS PR. WEEK IN

Physics/Chemistry.

1937	
6th	2 lessons
7th	2
8th	2
9th	2
10th	2

compulsory

70-75 % of the pupils left school after the 7th. form.

voluntary

middleschool-exams

secondary school-exams.

TOTAL NUMBER OF LESSONS: ca. 400 .

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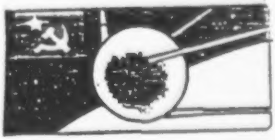
and then we got the SPUTNIK-chock



IN 1960 THE EDUCATION ACT OF 1958 WAS STARTED.

This Act pointed out that the education in physics and chemistry should be experimental. If a school was short of equipment for pupil's experiments it might loose its privilege of examinations. Luckily this Act was brought into life during the boom of the sixties.

LESSONS PR. WEEK IN

Physics/Chemistry.

1960				
6th	2 lessons			
7th	2 "			
	[illegible]	more	tech prep	sec sch tech
8th	2	2	6	X
9th	3	2	6	X
10th	2	2	6	5
TOTAL NUMBER OF LESSONS:	460	420	900	580

Even if directions were described in a dull and rigid way, something was put to action. The 'Sputnik chock' in the late fifties promoted the equipment situation, which was really needed. The full equipment from the 1814-Act was composed of one static electricity machine, one magnet, one glass prism and one globe.

ROYAL DANISH SCHOOL OF EDUCATIONAL STUDIES.

The establishment of a Teachers'Training School meant an important step forward for the improvement and development of the subject. The teachers employed at the Training School were scientifically well educated and open-minded, they also took interest in communication with the local teachers. The field of the institute was both physics and chemistry, even if the subject in school was called physics.

A close cooperation be een the union of teachers in physics and the institute gave birth to hundreds of courses all over the country. Later on the courses developed to last a year, a week or part of the summer holiday instead of one day. That really spread inspirations, technical and professional knowledge to the teachers participating. Consequently it became much more exciting to educate and to be the learner.

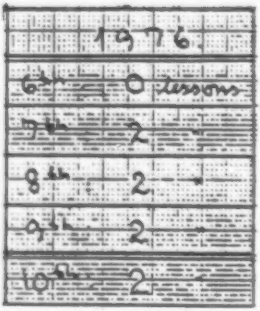
Once there was a saying in Denmark going like this:

'Every new minister of education makes a new Primary Act.' But the increasing speed of the passing governements showed some difficulty in keeping up with this. In 1975 a new Act replaced the one from 1958. The 1958-directions were published in one book all together. The 1975-directions had assigned one pamphlet per subject. The intension was clear, corrections and redoings concerning only one subject could be carried out cheaply and easily. Updating became a minor problem, - at least from this angle.

The 1975-Act was accomplished by a team of teachers, 'experts' and law people. As to the teachers there was an honest will to give equal status to physics and chemistry, - the subject was given the name of physics/chemistry to stress it. It was a surprise to find the allotment to be as unequal as 75% of physics when the final curriculum became available. The share in favour of physics was confirmed by the textbooks mostly applied.

LESSONS PR. WEEK IN

Physics/Chemistry.



1976
6th = 0 lessons
7th 2
8th 2
9th 2
10th 2

compulsary
after 9th form:
"school leaving exams"

voluntary

after 10th form: "school leaving exams" or
EXTENDED SCHOOL LEAVING EXAMS.

TOTAL NUMBER OF LESSONS: 9.th. form students: ca. 180.
10.th. form students: ca. 230.

THE PERIODICAL "FYSIK/KEMI".

The teachers of physics/chemistry got their own periodical in 1974, with a regular editorial staff for physics, chemistry and electronics. Lots of hints and ideas have been passed on to the teacher in charge, especially the one who does not feel too capable.

RADIO- & TELEVISION PROGRAMS.

Kemi i hverdagen (3)
KEMI i
HVER-
DAGEN

HVAD
SPISER
VI?
Superbox A/S

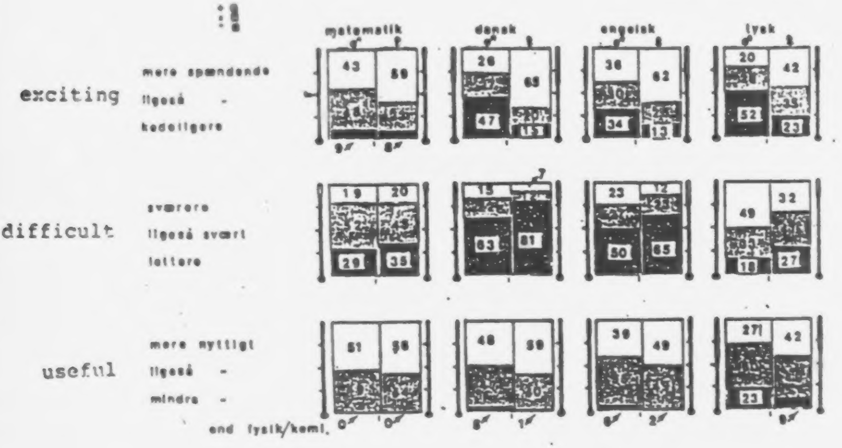
I think the intention of the old 1814-Act is revived by these programmes on TV.

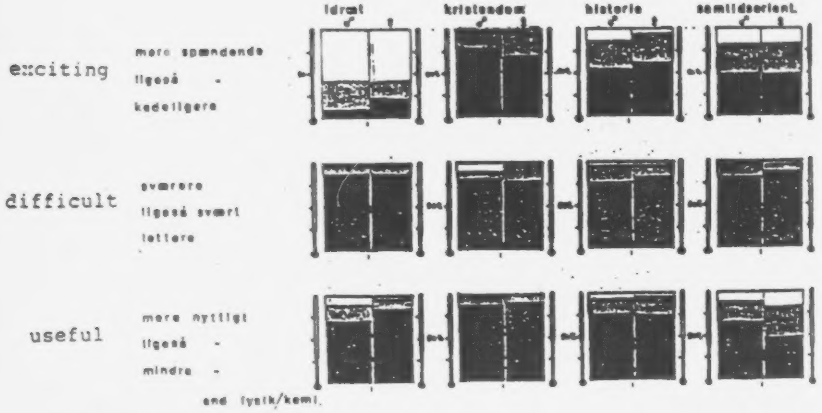
A nice contribution to shape up physics, and even more chemistry, is a series of programmes on TV produced by Radio Denmark meant for educational use. They are not coherent but have in common that the topic chosen is always exciting, relevant and of current interest. The booklets to go with the programmes are certainly qualified for a ten to fifteen lesson-curriculum.

WHAT DO THE PUPILS MEAN ABOUT SCIENCE EDUCATION.

Why is it that the subject is one of the most favoured by the 16-17 year olds? My guess is that the textbooks edited on the base of the 1975-Act are well qualified. The fact that there is a test at the end of the education, giving it high status and power may play a part as well. And I certainly hope that the interest taken by the pupils has its share too.

A year ago I performed an investigation together with professor Poul Thomsen, Institute for Physics, on the attitude to physics/chemistry. The inquiry addressed 900 pupils at an age of 15-16 years.

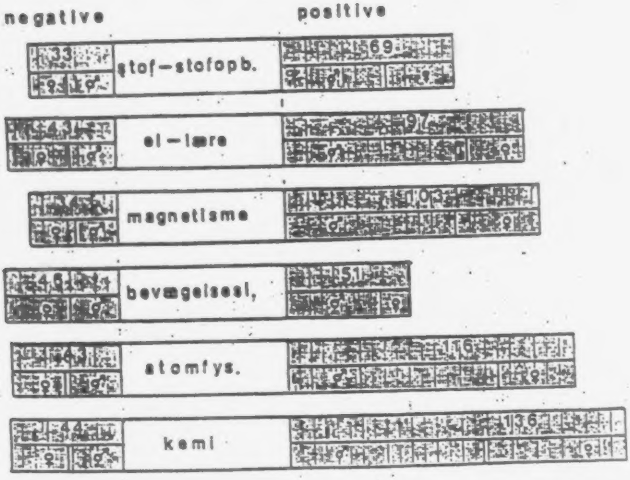




To know how the pupils felt about physics/chemistry they were asked to describe their likes and dislikes in six fields:

1. substances and their structure.
2. electricity science.
3. magnetism.
4. kinetics and mechanics
5. nuclear physics
6. chemistry (inorganic).

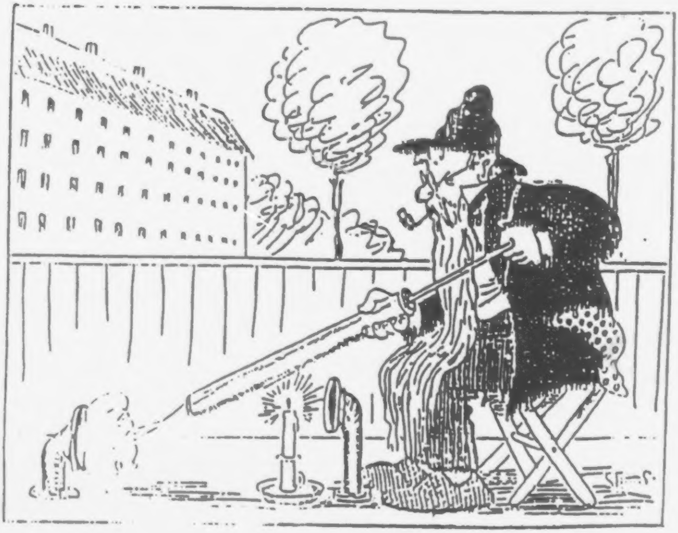
Chemistry showed to be the item responded to by most pupils. Chemistry was best liked out of all six topics. If the girls paid an interest to the subject, the chemistry part was chosen most frequently.



Many teachers would prefer that PHYSICS/CHEMISTRY became an optional schoolsubject. I believe that it would have a fateful and disastrous effect - it would be committing suicide. Biology and Geography became optional school subjects in 1976. Today 9 % of the students in 8.-10. form follow the education in biology and only 3 % geography :

SOMETHING TO THINK ABOUT.

"That people can learn is an undeniable fact.
That people can teach is an interesting hypothesis
that still remains to be proven!"
(Jacobovits)



is that the way, we are teaching SCIENCE ??

COULD THIS BE TRUE ?????

1. Don't believe that children are able to understand physics.

   PHYSICS IS FOR ADULTS !

2. Don't believe that ordinary people are able to understand physics:

   PHYSICS IS FOR EXPERTS !

3. Don't believe that women are able to understand physics:

   PHYSICS IS FOR MEN !

4. Don't believe that physics teaching is able to give youngsters wonder and delight - or even fun.

   PHYSICS IS EXACT MEASUREMENTS AND COMPLICATED FORMULAES !

5. Don't believe that physics has any connection with imagination, intuition or feelings.

   PHYSICS IS LOGIC !!!

SMALL GROUP

AND

PANEL DISCUSSION

REPORTS

NORDIC COOPERATION IN SCIENCE AND TECHNOLOGY EDUCATION
Report of discussion group No. 1 on May 9, 1985.

Hannu Kuitunen

The discussion group had representatives from Denmark, Finland, Norway, and UNESCO.

In the group it was noted that each Nordic country is a relatively small unit when development in education is considered. The opinion of the group was that common projects in the area of science and technology education among the Nordic countries will be profitable and possible. A better exchange of information about effects in science and technology education is needed.

Acting as a group, the contribution of the Nordic countries to international cooperation in science and technology education could be enhanced.

It was agreed that the Unesco network for information in science and technology education offers a suitable frame to organize such common efforts.

Recognizing these factors the group suggests the following proposals be supported by the conference:

1. In each country efforts should be encouraged to create a national network for information in science and technology education to work as a part of the international network created by UNESCO.

2. A Nordic Conference on Science and Technology education should be organized once every two years. The next conference is suggested to concentrate upon the following themes:
   - the public image of science and technology education (girls and science, the public opinion etc.)
   - science and technology education and industry
   - interdisciplinary teaching
   - science education as a discipline
   - computers in science and technology education

3. Information about events concerning science and technology education in each Nordic country should be distributed in the whole region. A possible means of doing this is to establish a Nordic Journal of Science and Technology.

Members of the group:

Sheila Haggis, Unesco
Poul Erik Hansen, Denmark
Nils Hornstrup, Denmark
Hannu Kuitunen, Finland (chairman)
Leif Lybeck, Sweden
Erik Thulstrup, Denmark (part time)

BIOTECHNOLOGY IN THE SCHOOL

Report of small group discussion No. 2 on May 9, 1985.

O.E. Heie

The purposes of teaching biotechnology, and also the methods, in the primary school and the secondary school are different. The techniques themselves and the scientific results are essential in the secondary school, where the aim of education is academic efficiency and preparation for continued studies. Teaching in the primary school shall prepare the pupils to be generally well-informed, responsible, and active citizens.

The ultimate aim is that a personal and active attitude based upon a certain insight is chosen.

This means that the individual is able to and also wants to get involved.

The group discussed the problems connected with politicians' presentation of questions to the population to provoke an open debate on topics little known or unknown to the majority of people, e.g. the question of future energy policy.

The biotechniques, especially in-vitro-fertilization and screening of human embryos, cause unsafeness. People are afraid that we shall be able to get too much knowledge of human genes because it demands an increasing number of difficult decisions. It will be more and more difficult to decide if a child shall be born or not.

It is necessary to get knowledge enough to get a reasonable chance to understand what experts explain. The political decisions depend on the individual citizen, so the personal decisions affect the development of the community.

The attitude shall be personal, but teaching cannot be neutral. Biological as well as social and humanistic approaches are needed. Knowledge of the economic forces are important.

The techniques can be subdivided into two kinds, those affecting production and those affecting reproduction. The former, in which the boys seem more interested, are mainly economically evaluated, while the evaluation of the latter, in which the girls seem more interested, primarily is ethical.

It is important that the pupils are prepared to seek further information on problems in their future life. The basic knowledge given in the school shall be that necessary to ask the right questions.

Training in making ethical consideration can probably best be carried out in situations where the pupils play distinct roles so that they get involved in concrete decision making. Information on the view of other people should be added.

Members of the group:

Ole E. Heie
Flemming Libner
Siw Skrøvset
Jan A. Andersson
Anita Ferm
Knud Johnsen

SCIENCE AND TECHNOLOGY EDUCATION: COOPERATION WITH DEVELOPING COUNTRIES, held on Thursday, May 9, and

LABORATORY WORK AND LOCALLY PRODUCED EQUIPMENT, held on Friday, May 10.

The following persons attended one or both discussion groups:

J.V. Kingston	Birgit Tejg Jensen
Frits Abildgaard	A. Kornhauser
Yuri Alferov	R. Pohjoranta
J.J. Christiansen	Krishna Sane
Hilde Harnæs	Svenn Wøjdemann

The groups discussed several aspects of science and technology eduation with special concern at the ways and means of cooperating with developing countries. The areas which are the focus of attention of science educators all over the world include

(a) Development of simple equipment
(b) Laboratory experiments
(c) Software for computers
(d) Audio-visual material
(e) Interdisciplinary approach to teaching of science.

It was felt that the Nordic Centre should take some initiatives in arranging collaborative programmes with the developing countries of the South-Asian region. This can be first done by exchange of information between the interested persons on both sides. This should be followed by an exchange of materials like equipment, videotapes, etc. which have been developed on either side. The third aspect can be an exchange of scientists especially in the younger age group so that the expertise available at one place can be used to train potential users at the other place. Some members of the group felt that agencies like DANIDA etc. should be approached for raising funds for such collaborative projects. It is also important that all the programmes undertaken should be time-bound and properly reviewed from time to time.

CURRICULUM DEVELOPMENT: SCIENCE IN SOCIETY

Participants:

Christensen, Claus	Denmark
Heikkinen, Henry	USA
Josephsen, Jens	Denmark
Lybeck, Leif	Sweden
Meisalo, V.	Sweden
Nielsen, Henry	Denmark
Paulsen, Albert	Denmark
Ringnes, Vivi	Norway
Strömdahl, Helge	Sweden
Tullberg, Aina	Sweden
Veje, Carl Jørgen	Denmark.

The discussion took place in a very relaxed atmosphere, and the group soon concentrated its efforts on giving useful advice to potential curriculum developers in this important field. A general consentus was reached upon the following recommendations:

- All students should at least sometimes during their science teaching be confronted with a Science and Society course in order to become aware of the enormous influence of science on our daily lives and on the technological development of our modern societies.
- Science in Society courses may be very different in character; no particular philosophy can be singled out as the best one.
- The development of Science in Society curricular materials will often get started at universities or teacher training colleges but to be successful it is absolutely necessary to get practical school teachers involved in the development work. They are the ones who can contribute exciting educational ideas which will eventually sell the material to teachers as well as to students.
- Social science people should be consulted during the development work. Otherwise one runs a great risk to oversimplify social issues in an unacceptable way.
- In the development of Science in Society courses one should probably always start from the basic scientific ideas one wants to present to the students. Then select an interesting and motivating issue as object for a case study which will serve a double purpose, namely to cast light on the relevance of science to society and to lead to a better understanding of the fundamental physical or chemical ideas by the students. Projects without a nucleus of basic scientific knowledge have no value from an educational point of view, since no transfer can possibly take place to other situations which are only a little different from the case actually studied.
- Finally, it is no doubt a very good idea to find a well-known scientist to recommend the project!

NOTES FROM THE DISCUSSION GROUP "SCIENCE TEACHER TRAINING".

Participants:

Aina Tullberg
Leif Lybeck
Veijo Meisalo
Helge Strömdal
(Erik W. Thulstrup)

The group agreed, that the pedagogical studies of science teachers should be properly content-oriented. It is important for a teacher to be able to analyse the contents to be taught, its structure, difficulty, etc

The scientific background behind teachers' daily work is the "science of science teaching". The group strongly favoured the use of terms "Didactics of Chemistry", "Didactics of Physics", etc. for these sciences. These should be developed as diciplines on the university level.

An essential part of teacher education should consist of getting experience of research and development work related to didactics of the relevant subject. It may include e.g. development of new educational materials.

During teacher education also open attitude for continuous education as well as for picking up new ideas, should be developed. On the other hand, resources for in-service education of science teachers should have especially high priority in the future.

MICROCOMPUTERS IN SCIENCE AND TECHNOLOGY EDUCATION

The discussions in the group on educational computing were atypical, in comparison with the discussions in the other groups. The group was not a small group, it was a rather crowded discussion room. And the participants spent quite a lot of time watching demonstrations of several packets of educational software, instead of having discussions.

In the discussions a short introduction to educational computing was given. Different modes of use of the microcomputer in education were mentioned. Distinctions were made among:

1) computer based aids, including systems for word processing, spreadsheets, programs or data collection

2) the computer as a teaching machine

3) the computer as a simulator: simulation and microworlds

4) databases

In the short discussion that followed,

it was often emphasized that the computer as a teaching medium is easy to misuse. It is easy to forget that thinking on educational computing does not mean thinking on computers, but thinking on education.

Ref. Bent B. Andresen

Participants:

Svenn Wejdemann, Denmark
Helene Sørensen, Denmark
Siw Skrøvset, Norway
Vivi Ringnes, Norway
Chr. Petresch, Denmark
Albert C. Paulsen, Denmark
Peter Norrild, Denmark
Henry Nielsen, Denmark
Aleksandra Kornhauser, Yugoslavia
Nils Hornstrup, Denmark
Henning Henriksen, Denmark
H.C. Helt, Denmark
Henry Heikkinen, USA
Hilde Harnes, Norway
Anita Fors, Sweden
Bent B. Andresen, Denmark
Jan Alfred Andersson, Norway

CURRICULUM DEVELOPMENT: MOTIVATION FOR CAREERS IN SCIENCE AND TECHNOLOGY

Chairman: Birgit Tejg Jensen
Participants: Flemming Libner, Knud Johnsen and Tapani Kananoja

The conference lectures and discussions have left the impression of confusion about the conception of the phenomena Science and Technology. We define Science as Biology, Chemistry, Geology, Matematics and Physics. Technology is defined in the conference paper of Knud Johnsen: Biotechnology at the secondary level.

The conference is perhaps mainly concentrated on Science teaching at primary school level, although there are very few people with daily practice in this school system among the participants. This stresses two problems: 1. The organisation of primary school teachers and the lack of intense coordination between primary- and secondary school teachers and university teachers. 2. Our ability to recommend curriculum alterations for the primary school.

Our principal proposals:

A. The curricula should be more interdisciplinary-problem oriented.

The childrens' world is not divided in disciplines e.g. Industrial production is a concrete factory: People working, raw materials, manufacturing, products etc. but not chemistry, biology etc.

B. Preparation of teaching materials.

Teachers of the science elements in the subjects do not necessarily have to be science teachers. In Danish schools problems like nuclear energy, nuclear war etc. are treated in social science disciplines. The fundament for this teaching is grassroot movement and newspaper publications. If we want science presented in a different way, we need to produce some alternative teaching material.

C. Sciences are hard disciplines

We shall not cheat the youngsters to believe that natural science studies are an easy challenge to the intellect. When the children are matured to formal thinking, at the age of 14-15 years, the science teachers can begin to create a deeper understanding of the disciplines, eventually using the science elements of a few problems as motivation for a deeper understanding.

INTERDISCIPLINARY SCIENCE EDUCATION

Chairman: Birgit Tejg Jensen
Participants: Yuri Alferov, Sheila M. Haggis, Krishna V. Sane
og Svenn Wøjdemann.

Some of the problems discussed at this small group discussion were strongly related to the conclusions of the small group discussion, Curriculum development: Motivation for careers in science and technology. The meaning of interdisciplinary teaching was referred to the definition in Terminology of science and technology education, Unesco International Bureau of Education 1984:

> "Teaching in which the sciences are linked together and possibly with other subjects such as mathematics, history, geography. This may or may not involve a multidisciplinary team of teachers working together".

We could conclude that

A. Interdisciplinarity is dependent on local/individual conception of disciplines/school subjects.

B. Interdisciplinary teaching is often focussing on a problem in the "real world", often more relevant to the children than the traditional subject examples. Among others we can point out some problems as severe hindrances for introduction of interdisciplinary teaching in the primary school.
The traditional teacher education and the organisation of teachers in discipline unions give a strong tendency to stick to the subject teaching.
The normal time schedules for the primary school must be partly reorganized.
Interdisciplinary teaching is time consuming.

SCIENCE AND TECHNOLOGY EDUCATION: BIOLOGY

Ole E. Heie, Denmark
Knud Johnsen, Denmark
Flemming Libner, Denmark
Siw Skrøvset, Norway
Jan Alfred Andersson, Norway

The group discussed the problems and possibilities of science and technology teaching of different school levels.

In the primary school we find it important that the pupils are motivated through their own experiences not to loose their curiosity to the physical world (the environment and their body). They should learn to use there senses, and the subjects should be handled creatively on basis of the pupils investigations and experiences.

But we need (at least in Denmark) qualified teachers, and we find that a main reason for the lack of interest in the sciences at the higher levels is due to the lack of qualified science teaching in the primary school.

In the lower secondary school the pupils should be trained in problemsolving. But the problems have to be real and relevant to the individual or the society - and not"model-problems". Real problems are interdisciplinary, and the sciences must therefore be an integrated part of the total education. Again we need qualified teachers, and we recommend team-teaching between science teachers and teachers from other areas (social science, mother tongue etc.). Examples can be environmental problems, sound, use of resources, production or "life-style" (use of computers, sex, fast food, test tube babies etc.).

In the upper secondary school the training in problemsolving should be continued together with a preparation for further education. In biology the following themes are central:Production and technology, nature and environment, health, and biology as a science, giving the students a broad insight and understanding of biological disciplines (ecology, genetics, biochemistry, physiology etc.) and their application (biotechnology, agriculture, environmental management etc.). The education must include laboratory work as well as field-studies in order to train the students to analyse and criticize scientific methods and results.

SCIENCE AND TECHNOLOGY EDUCATION:
PHYSICS
Small Group discussion. May 11.

Participants: Claus Christensen
Hilde Harnæs
V. Meisalo
Henry Nielsen
Albert C.Paulsen (chairman)
Christian Petresch
Carl Jørgen Veje.

1. Technical aspects.

Physicsteaching has a special obligation concerning the technical aspects of complicated modern Technology.

The technical topics should not be formally specified in a curriculum. They should be about wellknown technical material for the purpose of exemplification and demystification of technology. Also basic concepts in Physics should be examplified by more simple technical material.

The purpose of demystification especially applies to modern informationtechnology. "Looking inside" a computer can only be done in Physicsteaching whereas computerizing can be taught and used in special courses or in different disciplines.

2. Vocational aspects.

Physics and Technology teaching has significant vocational aspects. It was claimed, that modern industry need people with specific skills, which especially may be advanced in Physics and Technology teaching. The keywords of these skills are analyzing, organizing, cooporation and decisionmaking. But developing these skills in the Physics Laboratory in schools can not be done if teaching is tight up by a specified curriculum with a rigid syllabus. Also for the reason of developing vocational skills the curriculum has to be open and flexible.

3. Social and political aspects.

The social and political aspects must be part of the teaching of Physics and Technology. They are of course important matters in the social sciences, but they have also to be considered in their proper scientific context. Physics teachers are usually afraid of getting involved with political aspects. On the other hand this seems not to be a problem in the social sciences where politics is part of the curriculum. Consequently the possibility of including the issue in the curriculum in a more formal way should be considered. Some countries seems to have succeeded in including energyproblems and energypolitics in their curriculum.

SCIENCE AND TECHNOLOGY EDUCATION:
CHEMISTRY IN GENERAL

Jørn J. Christiansen
Helene Sørensen
Henry Heikkinen
Yngve Lindberg
Jens Josephsen

A major problem was localized, concerning the interface between science teaching in the lower secondary school and that of upper secondary school. When entering the upper secondary school, the students' actual knowledge about science and technology vary very much, and what is learnt in the lower secondary school is often not recognized. The training of science teachers for the two different schools are very different (in Denmark at least). This contributes strongly to the problem. Extension of the cooperation between different science teachers associations across existing "borders" is highly recommended.

STUDENTS' UNDERSTANDING OF CHEMICAL CONCEPTS

The group consisted of: Vivi Ringnes, chairman (Norway), Leif Lybeck, Helge Strömdahl, Aina Tullberg (Sweden), Raimo Pohjoranta (Finland) and Poul Erik Hansen (denmark). and part time Erik Thulstrup.

It is important that people who do research on "Students'understanding of natural science concepts" in the Nordic countries, talk to each other and exchange ideas and information. The group discussed the possibility of organizing a larger Nordic meeting on the understanding of natural science and technology conceptions, misconceptions and alternative framework. The aims would be to

- inform each other on the different projects run, on future possible projects, on journals etc.
- discuss the methodology used in the different types of surveys
- look for areas of common interest

and thus try to

- initiate studies of similar type to look for general patterns
- initiate different investigations in common areas to get a broader understanding.

Support for such a meeting could be applied for at different funds. Invitation to the first meeting should be sent to Universities, Teaching High Schools, Pedagogic Seminars, Science Teachers'Organisations, and National Boards of Education. Participants in the first meeting will elect a consultative group for further Nordic approaches in the field. A preliminary organising meeting will be held in Gothenburg in the middle of June, with 1-3 people from each of the Nordic countries. Vivi Ringnes and Leif Lybeck will be responsible for the planning of this preliminary meeting.

PANEL DISCUSSION

Members of the panel:

Sheila Haggis, chairman
Henry Heikkinen
Krishna Sane
Vivi Ringnes
Albert Paulsen
Yngve Lindberg
V. Meisalo

The chairman suggested five issues which could be of interest to discuss

a) A journal about science and technology education in the Nordic countries

b) Better cooperation in science education in the Nordic countries

c) Technology

d) Science and society

e) Computers in science education

Yngve Lindberg It is important to have science education in compulsory school. It could be combined with technology.

Vivi Ringnes The teachers in compulsory school need inservice training to be able to teach science and technology.

V. Meisalo The network UNESCO is setting up is good. It is too early to know if it will work. A journal in the Nordic countries is a good idea.

Albert Paulsen We have no material for technology teaching. You could have same teachers on a course and then let them educate other teachers in their area.

Krishna Sane It would be very important for developing countries to get information from the Nordic countries. India, for instance, would be happy for a copy of educational video programs, software and one set of equipment. It is also good to have an exchange of students and scientists. But you need a program and you need money. Maybe DANIDA, SIDA and the corresponding organisations in other countries, and UNESCO could support with money.

Henry Heikkinen	Why a network? Because the total is better than the simple sum of the individual parts. It is easy to share ideas. It is important that a network get some immediate results. The cost of transparencies, for instance, is very low and transparencies are easy to send by mail. We need more science in vocational education. We know science and can offer that to teachers in technical training.
Sheila Haggis	We are for Nordic cooperation.
Yngve Lindberg	We ought to choose one person in each country who should get the information and then send it to those who are interested .
Finnish participant	Suggestion: Each country should try to build a national network for information about science and technology education. The national network would work as part of the UNESCO network.
	A Nordic conference should be held every second year.
	- . - . - . - . - . - . - . - .
	A voting gave a majority for a conference in 19[illegible] den.
	- . - . - . - . - . - . - . - .
Yngve Lindberg	This conference 1985 can recommend each [illegible] h a national network.
Sheila Haggis	You can request money from UNESCO for, for inst[illegible] p about science and technology education. You have [illegible] rough the national committee.
	The chairman asked about a journal with information and descriptions of experiments, etc.
Henry Heikkinen	If every country had one responsible person, this person could collect information about meetings, workshops and experiments and you could create a rather simple newsletter.
V. Meisalo	You could arrange with a translation service in Finland. Perhaps the Ministery of Education in Helsinki could help.
Sheila Haggis	Perhaps you could start with a bilingual newsletter. Could Erik Thulstrup start voluntarily?
Erik Thulstrup	Could Norway instead?
Vivi Ringnes	Norway will probably start a national journal and will not take the responsibility for a Nordic journal.
	The chairman made the conclusion that it was not the right time to start a Nordic journal about science and technology education. She thanked everybody for participating in the conference.

CONFERENCE

SCHEDULE

WEDNESDAY, MAY 8.

4.00 - 6.00 p.m.	Registration
6.00 p.m.	Reception in Apartment No. 218
7.00 p.m.	Dinner

THURSDAY, MAY 9.

8.00 a.m.	Breakfast
9.00 a.m.	Opening of the Conference: Erik W. Thulstrup Henning Andersen, President of the Royal Danish School of Educational Studies
9.15 - 10.30 a.m.	Chairman: Leif Lybeck, Sweden Henry Nielsen, Denmark: A New Danish Science - Technology - Society Course. Background and Philosophy. (30) Albert Chr. Paulsen, Denmark: Science, Technology and Democratization - a Curriculum for Tomorrow? (15) Anita Ferm and Yngve Lindberg, Sweden: Report from the Stockholm Conference "Girls and Physics". (15) Helene Sørensen, Denmark: Girls and Science Education. (15)
10.30 - 11.00 a.m.	Coffee Break
11.00 - 12.30 p.m.	Chairman: Vivi Ringnes, Norway Henry Heikkinen, USA: Chemistry in the Community. (30) Hannu Kuitunen, Finland: A Visit to Industry as a Means of Motivating Learning in the Senior Secondary School. (15) Ole E. Heie, Denmark: Teaching of Biotechnology in the 8th-10th Grade. (15) Flemming Libner, Denmark: Experiences from Teaching Biotechnology. (15) Knud Johnsen, Denmark: Experimental Biotechnology at the Secondary School Level. (15)

12.45 p.m.	Lunch
2.00 - 2.45 p.m.	Chairman: John V. Kingston, Unesco
	Krishna V. Sane, India: A Model for Self-Reliance in Science Education Resources. (45)
2.45 - 5.45 p.m.	Small Group Discussions:
Apartment No.215	1. Nordic Cooperation in Science and Technology Education. Chairman: Hannu Kuitunen, Finland.
" " 114	2. Biotechnology in the School. Chairman: Ole E. Heie, Denmark.
" " 214	3. Science and Technology Education: Cooperation with Developing Countries. Chairman: John V. Kingston, Unesco.
" " 119	4. Curriculum Development: Science and Society. Chairman: Henry Nielsen, Denmark.
" " 120	5. Girls, Science and Technology. Chairman: Helene Sørensen, Denmark.
6.00 p.m.	Dinner
7.00 - 10 p.m.	Informal Discussions

FRIDAY, MAY 10.

8.00	Breakfast
9.00 - 10.30 a.m.	Chairman: Yngve Lindberg, Sweden
	V. Meisalo, Finland: Futurology and Education of Physics and Chemistry Teachers. (30)
	Leif Lybeck, Sweden: Research in Science and Math Education at Göteborg. (15)
	Bent Christiansen, Denmark: Theory of Mathematics Education: Recent Developments and Major Problems. (15)
	Henry Heikkinen, USA: An In-Service Teacher Training Programme. (30)
10.30 - 11.00 a.m.	Coffee Break
11.00 - 12.30 p.m.	Chairman: Thor A. Bak, Denmark
	Leif Lybeck, Helge Strömdahl and Aina Tullberg, Sweden: Students' Conception of Amount of Substance and its Unit 1 Mole. (30)
	Christian Petresch, Denmark: Physics and Chemistry Experiments with very small Computers (ZX81 and equiv.). (15)
	Jørn J. Christiansen, Denmark: Home-made Equipment which Focuses on the Concept Amount of Substance. (15)
	H.C. Helt, Denmark: Science Education at the Secondary Level as a Preparation for Further Studies. (15)
	Yuri Alferov, Unesco: Activities of the International Bureau of Education within Science and Technology. (15)

12.45 p.m.	Lunch
2.00 - 2.45 p.m.	Chairman: Henry Heikkinen, USA
	Aleksandra Kornhauser, Yugoslavia: Searching for Patterns of Knowledge in Science Education. (45)
2.45 - 5.45 p.m.	Small Group Discussions:
Apartment No.216	1. Science Teacher Training. Chairman: V. Meisalo, Finland.
" " 214	2. Laboratory Work and Locally Produced Equipment. Chairman: John V. Kingston, Unesco.
" " 213	3. Microcomputers in Science and Technology Education. Chairman: Bent B. Andresen, Denmark.
" " 116	4. Curriculum Development: Motivation for Careers in Science and Technology. Chairman: Birgit Tejg Jensen, Denmark.
" " 114	5. The Terminology of Science and Technology Education. Chairman: Yuri Alferov, Unesco.
7.00 p.m.	Conference Dinner

SATURDAY, MAY 11.

8.00 a.m. Breakfast

9.00 - 10.30 a.m. Chairman: Krishna V. Sane, India

Leif Lybeck, Sweden:
A Survey of Swedish Research on Interests in Natural Science and Technology. (15)

Peter Norrild, Denmark:
Themes Relating Science and Technology in the Early Stage of the Chemical Curriculum - some Ideas and Discussed Examples. (15)

Vivi Ringnes, Norway:
The Understanding of Chemistry among (Norwegian) Students. (30)

Birgit Tejg Jensen, Denmark:
Interdisciplinary Environmental Education. (30)

10.30 - 11.00 a.m. Coffee Break

11.00 - 12.35 p.m. Chairman: A. Kornhauser, Yugoslavia

Carl Jørgen Veje, Denmark:
Teaching Energy and Mechanics in Grade 8 in Denmark. Which Topics? (15)

Claus Christensen, Denmark:
Changes in Science and Technology Education in Physics in the Danish Gymnasium. (15)

Svenn Wejdemann, Denmark:
Educational Traditions in Danish School Chemistry. (15)

Jens Josephsen, Denmark:
Focus on Everyday Chemical Experience in the School. Motivation of Narcissists and Concrete Thinkers? (15)

Poul Erik Hansen, Denmark:
Observations and Reflections on Everyday Chemical Phenomena in Introductory Chemistry. Formation and Use of a Common Minimal Base. (15)

Erik W. Thulstrup, Denmark:
Superstition or Science Education. (5)

Sheila M. Haggis, France:
Unesco Activities in Science and Technology Education. (15)

12.45 p.m.	Lunch
2.00 - 5.45 p.m.	Small Group Discussions:
Apartment No.116	1. Interdisciplinary Science Education. Chairman: Birgit Tejg Jensen, Denmark.
" " 114	2. Science and Technology Education: Biology. Chairman: Knud Johnsen, Denmark.
" " 118	3. Science and Technology Education: Physics. Chairman: Albert Chr. Paulsen, Denmark.
" " 212	4. Science and Technology Education: Chemistry in General. Chairman: Jens Josephsen, Denmark.
" " 120	5. Students' Understanding of Chemical Concepts. Chairman: Vivi Ringnes, Norway.
6.00 p.m.	Dinner

SUNDAY, MAY 12.

8.00 a.m.	Breakfast
9.00 - 10.30 a.m.	Reports from Small Group Discussions (5 min. each, in the same order as in the programme)
10.30 - 11.00 a.m.	Coffee Break
11.00 - 12.30 p.m.	Panel Discussion
12.45 p.m.	Lunch and Departure

LIST OF

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